ELECTRIC LIGHT FITTING

C. J. Ferguson May 1st 1893

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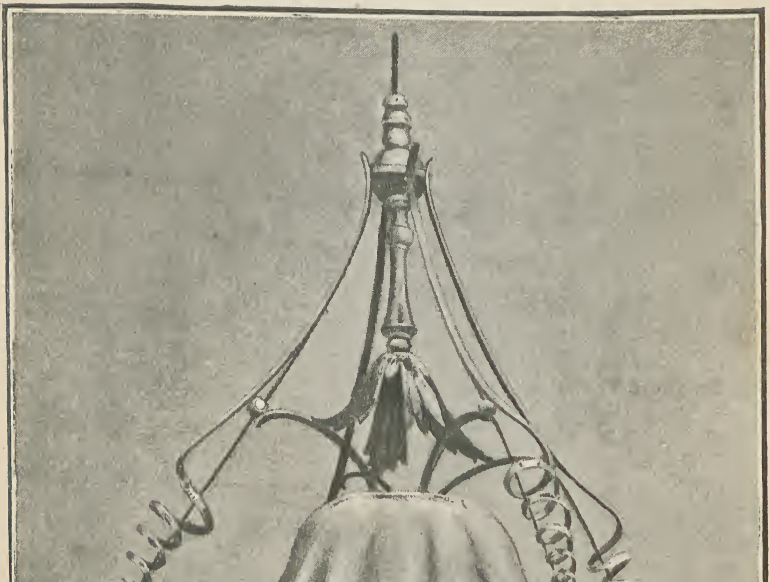

FOUR-LIGHT ELECTROLIER.

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ELECTRIC LIGHT FITTING

A Handbook for Working Electrical Engineers

EMBODYING PRACTICAL
NOTES ON INSTALLATION MANAGEMENT

BY JOHN W. URQUHART, ELECTRICIAN
AUTHOR OF "ELECTRIC LIGHT," ETC.

WITH NUMEROUS ILLUSTRATIONS

Capio Lumen

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PREFACE.

THE literature of Electric Lighting is already extensive, but when regarded from the working electrician's point of view it seems to leave much to be desired. Perhaps no branch of science carried into practice has been so generally favoured with the attention of eminent mathematicians as electricity. It is more than probable that, owing to this fact, the study of electric lighting is generally presented to beginners with a bias unduly favouring the *mathematical* aspect of the question. It is, of course, well known that it is impossible to study electricity without the aid of the higher mathematics. But only a limited number of those engineers who desire to acquire the knowledge necessary for every-day purposes are acquainted with even the symbols of the calculus ; and as so many previous writers of works on electric lighting are profound mathematical thinkers, a great deal of what has already been written (and which is, no doubt, most pregnant with thought) is, for the present, not available to the average reader.

There can be little doubt, therefore, that there is a great want of teachers who will not attempt to soar above the mental capacities and attainments of men who have received only a general education

The present volume is intended as an attempt in this direction. It consists mostly of the every-day notes of a working electrician, expressed in the simplest available language. It is addressed to intelligent men already engaged in the work of electric lighting, or training for it; and it more especially refers to the branches known as "fitting" or "wiring." The contents of the book will be found arranged more in accordance with the natural sequence of the work of electric lighting than in relation to the relative importance of the subjects. A general knowledge of electricity, and particularly of electric lighting, has been assumed on the reader's part. No attempt has been made to form a text-book, or to teach trained electrical engineers any part of their business: it is assumed that these gentlemen need no instruction from books. But some of the facts and methods dealt with in the following pages may, nevertheless, prove both new and useful even to experts.

The author gratefully acknowledges the encouragement that has been so fully accorded to his work on "Electric Light." He has also to thank those electricians who have kindly assisted him with information for the present volume, and the firms who have granted permission to publish diagrams of their latest productions.

June, 1890.

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ELECTRIC LIGHT FITTING.

CHAPTER I.

CENTRAL STATION WORK.

THE duties that fall upon the electrician in charge at a central distributing station vary considerably at establishments of different capacities. But those who are training for responsible posts of this nature, whether they aspire to the care of a City central station or to the charge of a simple "installation," will find it essential to be familiar with the following leading facts and principles :—

(1.) The particular fields of application of the separately excited dynamo machine (this type of dynamo may be considered a magneto machine, as well as the obsolete permanent magnet type). The uses of the series-wound dynamo. The particular application of the shunt-wound machine. The meaning of compound winding in its two main branches of what Professor S. P. Thompson terms short-shunt compound and long-shunt compound.

(2.) How to produce *constant current* from a dynamo. How to produce constant potential. The particular application of constant current and con-

stant potential must be known; *e.g.*, a constant potential dynamo will not necessarily run arc lamps in series, nor will a merely constant current machine run incandescent lamps in parallel.

(3.) The alternate-current dynamo, separately excited, is rising into importance, but its peculiar features are easily grasped by the student. The various methods of raising and lowering potential in this form of dynamo, by "coil grouping" and speeding, and varying the field must be familiarly known.

(4.) The nature of the magnetic circuit in a dynamo, and the meaning of "magnetic leakage" as applied to the machine.

(5.) The general management of dynamos, embodying foundation work; speeding; belting; governing, mechanically and electrically; treatment of the commutators and brushes and bearings.

(6.) Testing for faults or electrical leakage in dynamos, in mains, in branches, and in sub-branches (sometimes called "twigs").

(7.) The methods of running dynamos in parallel (particularly alternators used in incandescent lighting) and in series.

(8.) The application of voltmeters, ammeters, and other measuring instruments used in a supply station.

Separate Excitation.—Although formerly used chiefly for installations of arc lamps in series, separately excited dynamos are now largely used for incandescent lighting. In large distributing stations separately excited machines are almost exclusively (invariably so if alternators), used for feeding into the mains. The separate current is generally obtained from a smaller dynamo, series or shunt,

and sometimes compound-wound. The diagram (Fig. 1) is intended to show the disposition of the wire upon the separately excited machine. x represents the extremities of the field magnet coils, which are connected direct to the exciting machine; a shows the armature, commutator, and brushes, the current from which is led off as + – into the main wires of the lighting circuit.

Regulating devices of various kinds are frequently

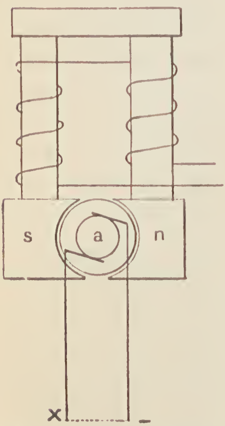


Fig. 1.—Separate Excitation.

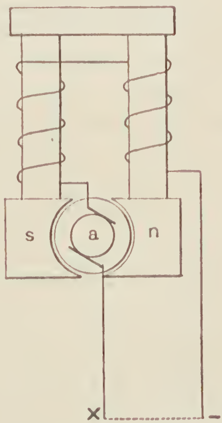


Fig. 2.—Series Winding.

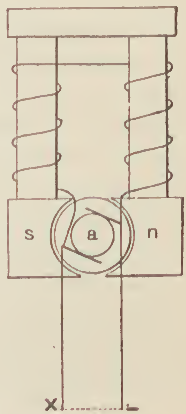


Fig. 3.—Shunt Winding

used, and placed upon the exciting machine circuit. A few of these are explained further on.

Series Winding.—For arc lamps placed in series, upon a circuit, especially if the demand for current be constant, as in street lighting, no arrangement has been found so generally serviceable as series winding. In this form of the machine the whole current from the armature circulates through the field coils. Such machines, to work satisfactorily, are generally made

with comparatively light field magnets, and with numerous convolutions on the armature. Fig. 2 represents diagrammatically the course of the current in a series dynamo.

But series dynamos are very generally used upon circuits in which the number of lamps varies or the call for current is not constant. In such cases the machine is regulated by automatic devices introduced into the main circuit. One form of dynamo (Thomson-Houston) is provided with a very efficient arrangement for shifting the position of the brushes upon the commutator as the current varies, and so causing the machine to evolve more or less current as required. Another dynamo (Brush's) is provided with a regulator which shunts off the exciting part of the current from the field in such proportion as may be required.

Shunt Winding.—It has been said that the series-wound dynamo is chiefly used for arc lighting, because it is well adapted for producing constant current as distinguished from *constant potential*, which is essential in the running of incandescent lamps. The aim of a builder of dynamos for incandescent lighting is to produce a machine in which the armature resistance shall be exceedingly small. As this resistance bears a very small proportion to that of the exterior part of the circuit such a machine is found to be nearly self-regulating, especially when wound in the manner known as "*compound.*"

Fig. 3 represents the arrangement of the winding in a common shunt machine. A continuous balancing of the current goes on in such a dynamo. The current, as it is taken off the commutator by the brushes, is divided in the inverse ratio of their

respective resistances between the field magnet and the exterior, or lamp, circuit. If the load of lamps increases, a larger proportion of the current passes through the shunt field coils, so strengthening the whole current. If the load of lamps be diminished, the process is the reverse of this.

Compound Winding.—For constant potential working, as in the running of incandescent lamps, a great advantage is gained by the methods of winding of the field coils known as compound. In this arrangement, which is becoming very common, two sets of coils are employed to excite the field, both series and shunt. In one form the extremities of the shunt coil are connected to the terminals of the main circuit. This is generally spoken of as a *long shunt.* In another form the shunt is connected to the brushes of the machine, known as a *short shunt.* As a rule, the series coils are wound first upon the magnet, and the shunt coils upon the outside. Sometimes the winding is the reverse of this; or they may occupy the same position with regard to the core, and lie side by side. The series coils are short and thick; the shunt coils usually long and thin. The shunt coil is usually so arranged that the machine will readily excite itself at low speed, *when the exterior portion of the circuit is open.*

Hand and Automatic Regulation.

Neither shunt nor compound winding has been found to meet the exigencies of all circuits, and the necessities of the different cases have called into use various devices for regulating the current supply to the demand. They are usually regulated by hand, or by some mechanico-electrical device upon the dynamo

itself. In the management of dynamos it is essential to understand the nature of the regulator, if one be used, and we therefore select for examples three methods, now very generally employed, both in isolated plants and in central stations.

Hand Regulator.—The device shown in Fig. 4 was introduced by Edison. It consists essentially of a shunt-wound dynamo, having in the shunt portion of the circuit a rheostat R, by means of which more or less resistance can be thrown into the shunt.

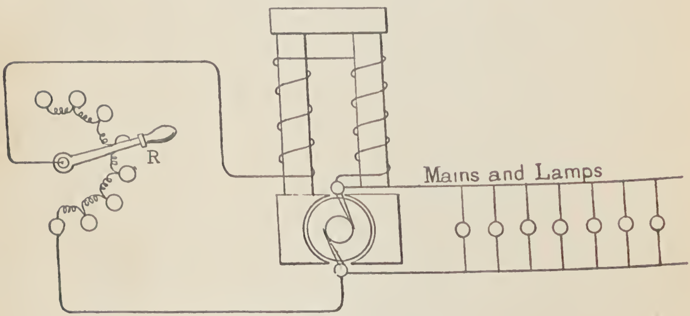


Fig. 4.—Edison Regulator.

Between each pair of studs is introduced a coil of iron wire, and, as the studs are connected in series, movement of the lever up or down will vary the length of resisting wire through which the shunted exciting current has to pass. This arrangement will be found very serviceable when the demand for current is fairly constant, or for adjusting the dynamo to a given number of incandescent lamps which are expected to be simultaneously alight. It is even in use in central distributing stations, chiefly for the incandescent lamp circuits.

Automatic Regulation.—If the demand for current is

variable, as in arc lighting or in public incandescent lighting, automatic quick-acting regulators must be used.

A very efficient form is employed by the Brush Company, chiefly for arc lighting, the simplest arrangement of which is represented as a diagram in Fig. 5. It may be used upon a series-wound dynamo. *a* represents an ordinary electro magnet (usually a pair of solenoids, with movable cores,

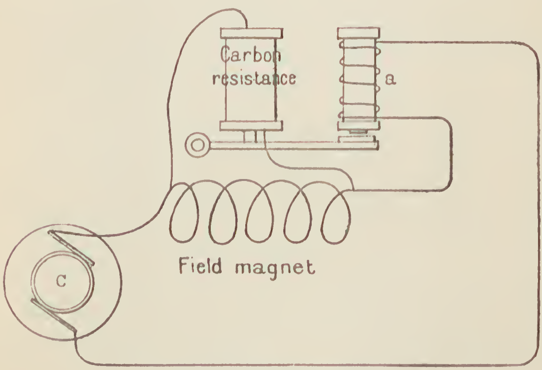


Fig. 5.—Brush's Regulator.

are used), the coil of which is in the main circuit from the dynamo *c*. When the current is normal this magnet exerts a gentle pull upon its armature. If several of the lamps in circuit become extinguished the current thereby increases rapidly. The regulator is designed to step in at this point and shunt off a portion of the current exciting the field magnets. This is effected by means of a carbon resistance column, consisting of a pile of carbon plates. In its normal position the electro magnet armature keeps the discs apart, but when the current from any

cause becomes abnormally strong its pull increases, the carbon pile is compressed, and a proportion of the exciting current is thereby short-circuited through it. The effect is to weaken the field and to reduce the potential and current. The property of carbon so arranged to vary its resistance in response to a slight pressure renders this form of regulator singularly efficient.

Lately Mr. Geipel added a relay to this arrange-

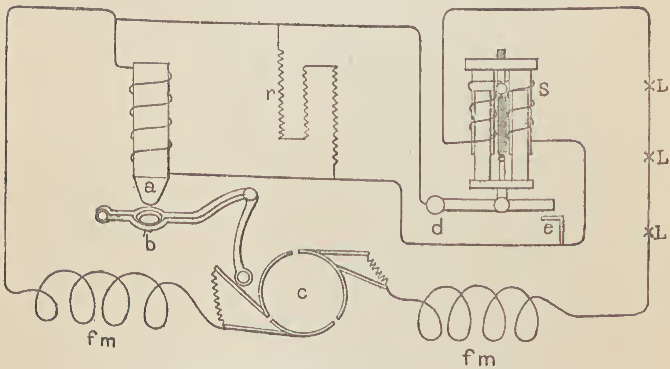


Fig. 6.—Thomson-Houston Regulator.

ment, by means of which it is rendered still more sensitive. It consists essentially of another double solenoid, controlling two contacts with the regulator solenoid wires. Upon an increase or decrease of the current taking place the relay instantly weakens or strengthens the action of the regulator coils, thus giving to the whole arrangement a double control, tor while the regulator adjusts for the field magnets the relay adjusts for the regulator.

Representative of another type of automatic regulator, Fig. 6 shows as a diagram the arrangement of the

Thomson-Houston device as applied to the dynamo of that name. a is a straight electro magnet, with a polar extremity of conoidal form, over which the ring-like armature bc moves when attracted. This form of pole and armature is used also in the Thomson-Houston arc lamp. It is adapted for imparting a long pull to the armature without the liability of coming into contact.

This electro magnet, the construction of which is

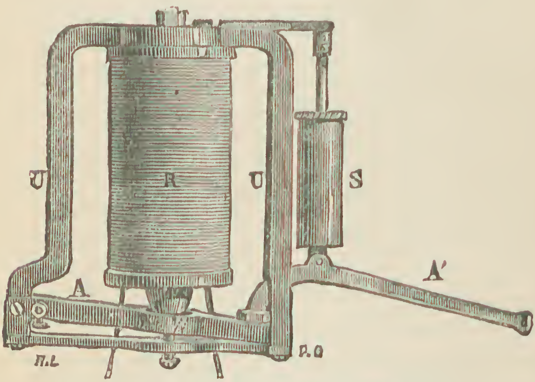


Fig. 7.—Portion of Thomson-Houston Regulator.

shown in Fig. 7, is placed in the main circuit of the machine, and its function is to *adjust the position of the brushes* upon the commutator of the machine e. It is well known that a change of the brushes from the normal position will result in a diminution of current. Normally the electro magnet is supposed to be short-circuited, through the by-pass wire leading to d, and is only brought into play by any increase or diminution of the current due to lamps being taken off or put on, or other minor causes. The electro

magnet is thus controlled by the current itself by means of the electro magnetic solenoids *s*, which are included in any convenient part of the circuit. These solenoids are more clearly shown in Fig. 8, and their function is either to *short-circuit* the brush regulating magnet *a* or to put it in circuit. Referring to Fig. 8, the cores of the solenoids C are supported in position by a spring S, and they carry upon their yoke a contact point O. If the current increases in strength, the solenoids pull up the cores and break contact at O, so throwing the regulating (brush) magnet into the circuit. Reverting to Fig. 7, the lever A and A′ carries a small air dash-pot S, to obviate jerky action of the parts, and in practice this lever is continuously vibrating and adjusting the brushes to the consumption of the current. The resistance *r*, Fig. 6, is usually composed of carbon, and is very high, its function being to absorb the destructive sparking which would otherwise occur at the contact *e*. The coils *f m* represent the electro magnet of the dynamo. The Thomson-Houston commutator is distinguished by the air-blast arrangement used to blow out the sparks evolved there. This sparking cannot well otherwise be got rid of in an armature of high tension with only three parts or coils. The high tension sparking is not,

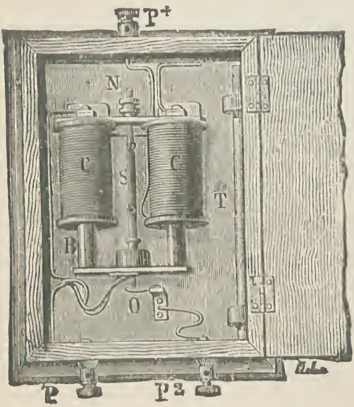


Fig. 8.—Portion of Thomson-Houston Regulator.

however, so destructive as that due to a larger current at a lower tension.

"*Lead" in the Adjustment of the Brushes.*—In a perfect dynamo, having no self-induction or other faults, the brushes would bear upon exactly opposite diameters of the commutator at right angles to the lines of force in the magnetic field. But in practice it is found that the most advantageous points for collection are a certain number of degrees in advance of this in the direction of motion; this is known as the *angular lead* of the brushes.

In ordinary series-wound dynamos used in arc lighting this position, once found, will generally remain constant. This is due entirely to the fact that the field magnets are in the main circuit, and any change of the current strength affects the *whole machine*, armature and field alike. But in shunt and compound-wound machines the relation does not remain constant, and the "point of best collection" may vary with the work in the circuit.

As a rule it is found that the point called neutral, or the point of *least sparking*, is the position of best collection for the brushes. In starting a dynamo this cannot be determined in any rough way until the machine is put upon full load at the normal speed. Both in relation to the output of the dynamo and to the wearing "life" of its commutator, the correct setting of the brush frame is of much importance. In well-designed machines the collecting points are always exactly opposite, and brush frames, although constructed to move a certain distance to the right and left of the collecting line, are usually fixed in relation to the diametrically opposed positions.

It will be found, notwithstanding the calculations

of several eminent electricians to the contrary, that even in dynamos with no iron in the armature, as in Siemens' alternator, or the Ferranti dynamo, "lead" must be given to the brushes. The "lead" was formerly supposed to be due to magnetic lag in the armature, but although this has undoubtedly its effect in dynamos built with iron armatures, it is not the only factor necessitating lead in the brushes.

Constant Position of the Neutral Point. — Many practical electricians suppose that the neutral point is apt to vary with the speed or output, or both. It may be of interest to note that in the experiments undertaken to determine this point by Mr. Mordey, with a Victoria dynamo and a Brush dynamo, no change in the position of the neutral point could be detected. This was true of the machines run under very different conditions of speed and load.

Notes on the Management of Dynamo Machines.

Foundations.—A great deal has been said as to the necessity for extremely solid or massive foundations. There can be no doubt that, when the dynamo itself is but flimsily constructed such a basework will be of great advantage. But when the machine is properly proportioned, and, especially, is fitted with substantial rigid brush brackets, heavy foundations are not necessary. Many dynamos perform well when merely bolted to the flooring of a factory, a sheet or two of vulcanised rubber, or better, of asbestos, being interposed. Heavy dynamos for permanent work should, of course, be carefully set upon substantial foundations.

In connection with the foundations it is interesting to note that in several small central stations, when the

dynamos are placed in basements of buildings, vibration and noise are successfully combated by separating their foundations from the walls. Thus, in the Grosvenor Gallery station the foundations are heavily laid in concrete, separated from the walls of the building by a foot or so of soft clay.

The chief objection to vibration is, no doubt, the evil effect it has upon the brushes, commutator, and other collecting or regulating devices attached to the dynamo. For instance, such a dynamo as the Thomson-Houston, with its controlling apparatus, &c., would fare badly upon a light foundation.

Erecting.—Large dynamos are usually delivered from the works in parts, packed separately. In bolting the carcase together it is necessary to observe particularly that the *magnetic surfaces* (forming part of the magnetic circuit) are not only clean, but freed from oil or grease. If there is any doubt upon this point a sheet of Oakey's No. O emery cloth should be used for clearing all such surfaces. Many dynamos refuse to excite, or magnetise, on account of carelessness in erecting. Not only must such surfaces be clean, but they must *touch all over*, and no nut must be tightened up until this is ascertained. In bolting down the main castings it is necessary to avoid buckling or twisting of the frame.

Armatures are by far the most important portions of dynamos. It may be pointed out that the armature is necessarily, although heavy, a delicate part of the machine. Precautions should be taken, by means of wood packing and supports, to avoid abrasion of its wires. An accidental scratch or dent has destroyed many armatures before they were placed in the machine. If possible, *always support an armature upon*

its journals, and keep it away from filings, turnings, oil, or grease. The commutator end of the armature should be protected from accidental dents or scratches. A case came under our observation in which the erecting engineer was seen to roll a heavy drum armature over an engineer's workshop floor, towards the dynamo frame. The armature had afterwards to be removed from the machine, and re-wound throughout its exterior envelope.

In erecting a dynamo it must always be borne in mind that if the running parts fit when *cold* they will become fixed when warmed up after the machine is started. End-play, to the extent of a fourth of an inch is therefore frequently allowed in armature journals, not only to allow for expansion when under load, but to assist in distributing the oil on the journals and to obviate ruts, or grooving, being started upon the surface of the commutator. For this reason, and on the score of economy of power and cool bearings, tight belting should be avoided. A belt too tight will speedily ruin a pair of journals and bearings, and will prevent end-play, with its advantages. When the armature is in position it should turn freely when moved by hand.

Speeding and Belting.—The normal speed of the dynamo is usually stamped upon it, corresponding to the volts and ampères it is estimated to yield. The driving motor should be well governed. If a gas engine is used it is a common practice to drive with a rather flexible belt, and to put a heavy balance-wheel upon the axis of the dynamo. Unsteady action of the engine or shafting will speedily be observed in pulsations, or dimming and brightening of the lamps. Gas engines that take gas once in every two or three

revolutions are very troublesome on the score of "pulsating" the lights. Such engines can, however, be speeded to take gas at every revolution.

Leather belting is being displaced for the larger dynamos by rope belting in several distinct strands. This presents the advantage that a total stoppage is less likely to occur by the slipping off of the belt, or by its breaking. The ropes are run in grooved pulleys, from three to any number being used. They are undoubtedly safer, more reliable, and cheaper than one large leather belt. Most of the smaller dynamos, up to 20 h.p., are, however, fitted for belts. Riveted belts should be avoided, and joining should be done by lacing, in the old-fashioned way. The belt should always be as broad as the pulley will take, otherwise slipping, at full load, is certain to cause trouble, unless the pulley is made extra long, to allow of the belt being run off a "fast and loose" pulley gear.

Ratio of Belting Surface to Power.—The usual allowance of breadth of belt per horse-power is one inch for high-speed belting moving at the rate of 1000 feet per minute. The rule is safe for belts from three to twelve inches in width. For slower speeds a wider belt must be used.

Lacing of Belting.—Lap, switch, or splice joints are very objectionable except for large work. For high-speed driving upon small pulleys *butt* joints have proved by far the best for dynamo work. It should be noticed that a belt that emits a noisy snap upon passing over the dynamo pulley not only causes fluctuations in the light, but sets the armature, if not the whole machine, in vibration. Hence, let the belt be cut perfectly square across both ends, and laced with an endless "thong" lace. The inside face should be

kept as flat as possible. New belts stretch enormously, and give a good deal of trouble in first runs. They may, therefore, be put on rather tight. Many engineers treat the harder belts with a dressing of sweet oil, frequently applied, so as to ensure pliability.

Brushes.—Each builder has his own particular pattern of brushes, and it is impossible to say which is the best form. But as to material there can be little doubt that hard-drawn or rolled copper, or phosphor bronze, gives most satisfaction in work.

Wire brushes appear to be going out of fashion. Comb-like brushes, made up from several layers of the metal, are coming generally into use. The pattern of brush sent out with a dynamo at first is generally the best for that particular machine. Two or three points may be noted—the brush should be of high conductivity; it should wear well; it should have a certain flexibility and resiliency; and it should be set in a brush bracket, *itself* provided with springs. This latter condition is of considerable importance—no commutator brush for heavy current work should be self-sprung. Only a gentle pressure upon the commutator is required; but there are two considerations that always control the amount of contact pressure. (1) In heavy, well-founded dynamos, giving currents of low tension, light pressure will be found best, because there is less vibration of the machine to cause weak contacts of the brush, and because low tension currents allow of a lighter touch without sparking: (2) For lightly-set dynamos, or those liable to vibrate, especially if giving high potential, stronger set springs are required. The snap of a badly-laced belt will frequently cause the contact to become weak periodically, producing, it may be, a burnt "spot"

upon one of the commutator bars. If once such a "spot" begins it will go on from bad to worse, and finally the whole surface will need to be re-turned. Other *periodic* vibrations, perhaps due to the dynamo itself, or to adjoining machines, may start a spot. If the vibrations cannot be eliminated then more pressure must be applied at the brushes.

Let the beginner bear in mind that the pressure cannot be too light, provided efficient collection, with the minimum of sparking, occurs. The commutator and brushes are the chief care and anxiety of the electrician in charge, in the case of long runs. If he can keep them in good order, and his bearings cool, he has learnt a practical lesson of much value to him. But a burnt spot, if found persistently upon the *same commutator bar*, after re-turning, is generally due to a *fault in the armature coil connected to that bar ;* that is, the neutral line for the other coils is not the neutral line for it; the coil is out of its place in the circle, or is connected in a faulty way. We mention this in connection with brushes because it is not always bad contact at this point that originates a "bad spot."

Treatment of the Commutator.—The simplest "Commutator" is that attached to an alternating current machine, consisting as it does of a pair of copper or gun-metal rings. These are of course very easily managed. There is no liability to sparking, no burning, no production of burnt spots. The rings may be lubricated when necessary, but only lightly, and preferably with vaseline or French chalk.

A *smooth* commutator is the chief aim of the dynamo attendant. It must present neither grooves nor patches, nor parts "out of round." To attain this result, when heavy current is passing from the sur-

face at a high speed of rotation, and for many hours together, is no easy task. But a great deal depends upon the make of the commutator itself.

Asbestos insulation between the commutator segments, which was formerly much used, gives a great deal of trouble. It easily, owing to its softness, receives into its surface copper dust or carbonised oil, and becomes a conductor, short-circuiting the bars. Various substances have been used, but experience appears to be greatly in favour of *mica*; but of this substance there are different varieties. Clean mica, free from foreign substances, and not too hard, is found to be the best for commutator insulation. When impure mica is used, or it is too hard, it does not wear away as fast as the copper, and ridges result with all their attendant trouble. The mica should wear quite as fast as the copper commutator bars. Some makers of dynamos have abandoned material insulation altogether between the bars, and have reverted to air-gaps. One instance of this is Siemens' latest dynamos, many of which have large iron commutators, insulated by air grooves. But this again will cause trouble if the grooves happen to get bridged across, an occurrence very likely with a paste of copper dust and charred oil, in long runs. In a good mica-insulated commutator there is no such trouble. We have never known mica to absorb any kind of conducting substance.

Commutators should be run without lubrication, but it is not easy to attain this. Attrition of the surface will speedily occur if there is the least roughness at first. To run a commutator dry it is necessary to have its surface even, round, and perfectly smooth—nay, burnished. *A rough surface is generally due to*

rough brushes. If the brush surfaces are burnished and bear upon a smooth commutator, it will be possible to run dry; but in first commencing work it is usual to slightly touch the revolving surface with oil, or, preferably, vaseline. A "touch pad" made by covering a flat piece of wood with several layers of cloth and saturated with vaseline, is very useful. This is not applied to the commutator. It is better to press the finger upon it, and transfer the layer of lubricant thus obtained to the commutator. More than a mere surface covering must be avoided. A new commutator, after a few hours' run, will under this treatment acquire a hard, brown, glossy surface, which it is very desirable to attain.

Roughness is generally treated by dressing with emery cloth. This should not be done, if it can be avoided, while the dynamo is in work. The brushes should be raised, and the No. O emery cloth wrapped around a block of wood. If these precautions are not taken, the emery powder will become embedded in the brushes, and continue to cut the surface for days thereafter. Indeed, emery, although a quick-cutting substance, should never be brought near a dynamo for this purpose. Many engineers prefer to use fine sandpaper or a leather pad with grindstone dust glued thereon.

For spots or grooves there is no effective remedy but turning in the lathe. Files are very often used, but it is quite impossible to thereby produce a true cylinder.

Large dynamos are now very frequently furnished with an accessory in the form of a miniature lathe, by means of which the commutator can be "trued" without removal from the machine. It is probable

that in future all large machines will be thus wisely equipped.

A very useful device has been suggested for this purpose by Mr. R. Tatham, who proposes to furnish the brush brackets with a slow to and fro motion in line with the axis of the dynamo, and to attach to the bracket a trueing tool or emery wheel for occasional correction. But although the reciprocating motion of the brushes themselves, as proposed, would no doubt be an advantage in itself, the gear for that purpose, consisting of a worm-wheel and tangent worm shaft, would be likely to introduce faults of contact or insulation in practical use. Whatever turning device is employed for turning in position it will be found necessary to run the armature at a slow speed. In the larger stations little machines are used both for this purpose and for trimming off the ends of brushes, especially that form in which contact is made by a bundle of wires or slips.

In the case of dynamos in which regulation is effected by rocking the brushes to and from the neutral line, the commutators are apt to give much greater trouble. There is usually more sparking, which cannot be avoided. It would appear that the Thomson-Houston dynamo does not suffer much from this cause, although, owing to the high tension employed upon the arc machines and the nature of the three-coi armature, there is a good deal of sparking. But the air-blast used in this instance both serves to keep the commutator cool and clean and to extinguish the sparks.

New Commutator.—Many of the best dynamos are accompanied as an accessory with a spare commutator, which can be fitted in place of the old by

observing particularly the method and order of connecting it to the armature wires. In removing the old wires, which are generally screwed to the bars, a "tally" or numbered tag should be tied to each wire, indicating exactly its position in respect to the bars of the commutator. The work of re-connecting is simple in cases where the wires are joined direct to the bars, and are not carried either to the rear or in advance of their positions upon the armature; but in many dynamos, *e.g.*, the Edison-Hopkinson type, the wires are taken 85 degrees to the rear, and there attached to the commutator. This method is adopted to allow of the *neutral* points—collecting lines—being placed in convenient positions for observation and adjustment of the brushes. Thus, instead of the points of collection being upon a vertical line, which would place the lower brush directly under the commutator, the line is nearly horizontal, and both brushes can be equally well observed.

The same method is adopted in some of the Siemens' dynamos, but in many of the best machines, where there is any likelihood of confusion in connecting, either the wire extremities are furnished with a stamped (numbered) plate for connection, or a diagram of the positions is obtainable.

Soldered connections are the most troublesome. The unsoldering is a tedious process. We may suppose the armature to be removed from the frame and placed upon supports at a convenient height. After clearing off the dust, &c., each joint should be touched with a drop of the zinc chloride solution used for soldering, and a pretty hot soldering bit applied to the spot. As soon as the solder runs the wire is lifted up, and the old solder wiped off its end. The work may be done

with a mouth blowpipe. For this purpose a gas jet, attached to a rubber tube without a burner will be found a convenient source of heat. The blowpipe flame can be directed accurately upon the joint and the work done very quickly. In resoldering the commutator must first be securely keyed upon the shaft and the bars at the connecting points scraped clean. Each point should then be touched with soldering fluid (Baker's is esteemed the best) and thoroughly "tinned" with the copper bit. It must be observed by those not acquainted with the use of a copper bit that the point must be freshly filed, and, while yet bright, the solder—previously moistened with fluid—applied. The bit itself must be thoroughly tinned, and after re-heating the point should be wiped clean. In resoldering the wire ends the wire is placed, without tendency to spring, upon the tinned commutator plate. A touch of the fluid is applied (be sparing in the use of this) and a drop of solder taken up by the bit applied to the joint. It should immediately run freely and make a clean, perfect joint. It is well to run on a little more of the solder by way of a strengthener. No difficulty need be experienced if the surfaces are *clean*, the copper bit *well tinned*, and *hot* enough to cause the tin to run freely. Joints made with resin as a flux are doubtless to be generally preferred, but the use of resin is not so easily acquired, and an imperfect joint is more likely to result in inexperienced hands. There is no objection to the use of Baker's fluid if sparingly used and each joint afterwards wiped clean. It may be pointed out that the careless use of common soldering fluid is very apt to leave joints that will become rotten, or waste away by electrolysis under the influence of the current.

In the case of screwed connections to the armature plates too much attention cannot be given to the preparatory cleaning of the points of contact, and to ascertain that each screw is tight enough in its hole to ensure its holding. If the screw feels loose in its hole while screwing up, it will soon work slack, and cause an arc to form, burning the contact. For this reason some of the later machines have both screwed and soldered connections, and in some cases silver solder, applied with borax as a flux and the blowpipe, is employed.

Connections of the Dynamo. — In erecting new dynamos the connecting of the field coils to the circuit of the armature, or otherwise, is sometimes a difficult point. It will first be necessary to ascertain exactly what type of machine the dynamo is represented to belong to. If a series-wound dynamo, a separately excited, or a shunt machine, the connection can be ascertained by reference to Figs. 1, 2, 3, p. 3. But certain symbols are generally used to distinguish the extremities of the wires and the terminals. Thus, + and —, positive and negative, are widely used to indicate the "feeding" and "receiving" ends of a coil, or terminals. White (or bright) terminals are also used for +, or positive, and black terminals (representing earth) for —, or negative. The terminals are frequently spoken of as live or leading for positive, and return or earth for negative. In connecting up a dynamo two positives are never connected together, nor two negatives.

After ascertaining the particular nature of the machine, its connections, if not numbered, will depend upon the direction of rotation. If the field magnet be connected up in a series machine so that the current

flows in the magnet so as to increase its residual magnetism it will be correct. Every dynamo magnet has a certain residual magnetism when the machine is at rest, and it may be desirable to ascertain which pole is N. and which S. This can readily be determined by means of a compass needle or a small magnet, for the N. pole of the dynamo will not attract the N. pole of the magnet, but it will strongly attract the S. pole, and *vice versâ*. The course of the current in that magnet will then be easily found according to the following rule :—

If a spiral of wire be taken, and a piece of iron inserted therein, and a current caused to flow in that wire in the direction of the hands of a watch, when the spiral is looked at end on, the pole of that iron nearest you is the S. pole.

Or, more simple still, If you look at a right-handed screw, the thread representing the current, the end viewed is the S. pole. This pole is, as applied to compasses and galvanometers, frequently called the "blue pole," from the custom of makers to leave the south-seeking pole blue and to brighten up the north-seeking pole.

In a separately excited machine the direction of the current in the field magnet should be particularly ascertained, otherwise the machine will yield — (negative) at its + (positive) terminal, and give rise to all kinds of trouble in the work of wiring for lamps.

If a mistake has been made, it may be rectified by strongly magnetising the field magnet by the passage of a current either from another dynamo or a battery of accumulators. This will have the effect of breaking down the residual magnetism and reversing its polarity.

When the dynamo is first started the current should be tested for direction by the use of a compass. Place a compass upon the ground; run a wire from the + pole of the dynamo over the compass and back (through a suitable resistance) to the – pole; if, while you stand with your back to the dynamo, the N. pole of the compass turns to your left hand, the current is flowing from the dynamo towards you, and is correct in respect to the positive terminal.

In a shunt, series, or compound machine, not much harm can result from starting it when wrongly connected with respect to the field magnet—it will refuse to excite, and will give no current.

When there is a resistance in the exterior portion of the circuit, and the dynamo refuses to excite, the fault is usually due to wrong connections. But a series dynamo will not excite readily at a *low* speed.

An ordinary compound (series and shunt) dynamo is connected correctly when the ends of the shunt (fine wire) coil are joined to the brushes, and the series (thick wire) coil joined, one end to the – (negative) brush, and the other to the – (negative) terminal. The current in both coils must of course flow in one direction around the magnet.

Run for Mechanical Test.—A run of several hours' duration should be made with a new dynamo to test the bearings, lubrication, stretch belts, &c. Hot bearings may gradually cool down if new after a few hours further running, but if there is any question of the armature shaft being out of alignment the heat will increase. The surface of the armature must be quite clear of the magnet, and in line with its bore.

All kinds of suggestions and substances have been recommended at different times as a cure for hot

bearings, but, provided the journals be lubricated, the fault itself must be got rid of. The chief causes of heating are doubtless, (1) belting too tight; (2) bearing too short for the work; (3) badly fitted, out of round, binding, or out of alignment. The lubrication should be of heavy oil or other lubricator of good quality. In long runs with heavy dynamos the bearings sometimes become so heated as to need the application of the hose—in cases where the load of the dynamo cannot be switched on to another machine and the current must be maintained. Hot bearings are of course made hotter by the current in the wires of the armature.

In the use of needle lubricators the needles frequently stick in their tubes, owing to foreign substances in the oil. The needles should be tested for free play before starting a long run. A hot bearing, perhaps to the extent of slight "seizing" or attrition, is generally brought about by neglecting this precaution. The semi-solid lubricants, fed from suitable spring lubricators, and which flow gently when warm, are being much used for dynamos. The chief fault to guard against is failure of the lubrication while the dynamo is left by itself for long periods of time.

Notes for Dynamo Attendants.

The attendant should understand his machine. One attendant can manage several dynamos if they do not call for much regulation. In isolated stations, where the demand for electricity is constant or nearly so, compound machines will be found to regulate themselves, and the exciting current once determined and applied, need not be varied.

But in central or "public" stations the call for current varies enormously. Taking a representative incandescent lighting station as an example, the diagram (Fig. 9) shows, beginning at noon and till 3 P.M. very little demand for current. Between 3 and 4 o'clock the demand rises rapidly from 10 to 150 units; by 5 o'clock it has risen to 350 units; at 6 o'clock to 500 units; and at 7 reaches a maximum of 600 units. It then gradually drops, until, at 2 A.M., there is practically no demand.

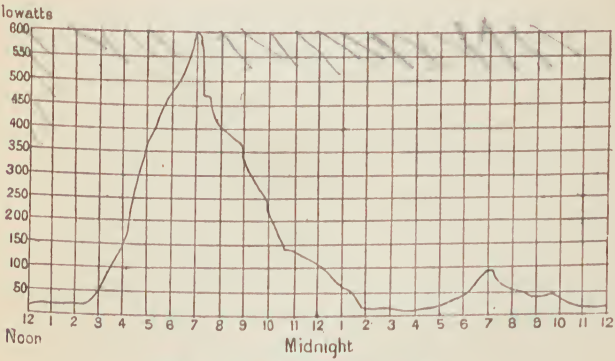


Fig. 9.—Time and Current Curve.

The requirements of such a station call for several dynamos to meet this varying demand. But one dynamo, with a good hand or automatic regulator, will be found to carry the scale up or down by itself for a considerable distance. In most central stations this regulation has hitherto been effected by means of observation and the hand.

It will be evident that the dynamo, to meet the ever varying conditions and continue the supply, must be well looked after. A few observations upon the main points likely to call for special attention are

therefore offered here, in the hope that they may prove useful not to trained electricians, who are supposed to be well versed in all the best methods of meeting a varying demand, but to members of that large class who are at present serving, as it were, a kind of apprenticeship to the business of electric lighting.

Heat and Attrition.—The dynamo attendant's bugbear is doubtless *heat*. Under a high speed the bearings are apt to get hot, and under a heavy load of lamps the armature and field magnets frequently get so heated that they cannot well be touched by the hand. There is therefore under these conditions a constant danger, or supposed danger, of "firing" the bearings or journals and burning the insulation of the wire coils.

Attrition, or cutting friction of the commutator, is another cause of trouble in long runs, but is more easily overcome than the overheating.

Bearings can be kept cool if at first well-fitted, if not too short, if not binding in the "neck," and if lubricated freely with a good oil or other lubricant.

Dry cutting of the commutator is due to rough treatment, rough brush surfaces, or grit, or emery, or to *too much pressure of the springs*. The larger dynamos are fitted with several brushes upon each arm of the rocker, and a brush that is cutting should be at once taken out. The pair should be taken out even while the dynamo is running at full load. Their roughened ends should be cut off and smoothed, then, if possible, *burnished*, using a brass finisher's steel burnisher for the purpose. This will impart a glass-like surface to the copper. The commutator should then be wiped clean with a pad of wash-leather, and

its rough surface smoothed, either with fine sand-paper or with emery cloth. But the use of the latter is not recommended. The smooth surfaces may then be lightly covered with the merest film of vaseline or oil, and the brushes replaced. A gentle pressure should be applied at first. When it is not possible to remove the brushes thus by instalments dry cutting should be at once stopped, as far as practicable. For this purpose, clean off the surface and apply either a flat pad covered with fine glass-paper, or, if that is not at hand, a chip of emery cloth, No. O. When as smooth as possible clean off and touch with vaseline. When the dynamo is stopped examine the pressure of the brush springs; it will generally be found that the attrition was due to this cause, in excess. The brushes should be removed and trimmed and burnished at the first opportunity. Avoid lubrication of commutator, if you can do so. Too much oil or vaseline will cause long, circular sparks to leap from segment to segment, greatly weakening the current.

Heated Armature and Field Coils.—When a well-designed dynamo heats too much it is overloaded. Lamp after lamp has been switched in until the current has become too much for the wires. It would be better to see the belt slipping than the coils becoming overheated. But, in respect to overheating, it is not always synonymous with overloading. In many of the earlier dynamos this excess heat is due to "eddy currents" set up in the iron of the armature, owing to its imperfect subdivision. A very instructive instance of the enormous advantage of subdivision may be referred to. The Brush dynamo, with "solid" armatures, as first introduced, and in use in this country until very recently, will, taking one specific

size, the 16-lighter, when fitted with the new laminated armature, give 25 lights in each case without overheating.

In a central station the only way to effectively reduce the heat of an overloaded dynamo is to switch in another machine, which will take half, or a proportion, of the load. The heated coils will then gradually begin to cool down. In the early days of electric lighting a fan was used to keep the dynamo cool.

It is part of the duty of the electrician in charge, more than that of the dynamo attendant, to ascertain the full working load of his machines, and to issue instructions for a watch to be kept upon the indicators, so as to determine when the current is reaching a maximum, and it is time to switch on a fresh machine. It is scarcely necessary to remind the attendant that water cannot be used to cool a heated dynamo.

Hints and Suggestions.—Keep iron and steel tools away from the machine; never file iron near to a dynamo. Lubricate with a brass, copper, or zinc oil can. Leave your watch at home, if it is an ordinary watch. Have a pair of bellows for blowing away all dust, especially metallic dust, from armature coils. Do not spill oil or water near to or upon a machine. Prevent by shields adjacent machinery from throwing oil upon the dynamo.

Tighten all binding screws afresh every day. Test nuts and bolts occasionally for tightness. If a binding screw is loose, examine it for burned surfaces, and file off a fresh surface. Adjust brushes as to pressure before starting, and as to attaining the neutral point —point of no sparking—after starting. Never lift a brush while the current is on—you would make a burned patch upon the commutator.

Personal Precautions.—Never close a circuit of any dynamo, or, indeed, any circuit, through your body. It may be done by inadvertence, and not through the hands only. Many of the earlier electricians received severe shocks by merely touching a wire or terminal with one hand. This is generally due to *ground leakage*, and a pair of rubber overshoes would prevent it. But, as a general rule, never touch a wire or terminal, either with one or both hands, or with any metallic article, while current is on. If terminals need attention, an insulated key or spanner must be used, or put on a pair of thick rubber gloves.

All spanners, plyers, and adjusting tools in general, used in a dynamo room, or switch room, should have insulated handles of ebonite, or other good insulator.

Shocks of enormous tension—probably over 1000 volts—have been freely taken by many boasting persons, but it may be pointed out that the deadly nature of the electricity is not its tension merely, but the quantity or current passing, combined with high tension. A discharge of many thousand volts can easily be taken upon the knuckles of the hand, without injury, from a Leyden jar, but the same tension in a cable carrying a current of 1000 ampères would not only burn the hand but be pretty certain to kill the adventurous experimenter.

Attention to Automatic Governors.—The general impression among electricians has hitherto been that an automatic governor for public incandescent lighting is not reliable, and that hand governors only are to be depended upon, but this impression is wearing away. It is necessary, however, for the attendant to keep an eye upon both current and governor, no matter of what design, during the whole period of the run.

CHAPTER II.

LOCALISING DYNAMO FAULTS, AND OBSERVATIONS RESPECTING ACCUMULATORS.

A DYNAMO may sometimes unaccountably refuse to excite and to start. If separately excited it may refuse to give any current. This is the greatest of all faults, but it may be due to a serious defect, or simply to a very small fault, easily remedied.

But by far the most frequent complaint is due to *partial* failure of current; to fluctuations, usually sudden, in the current strength, and to occasional unaccountable extinctions of the lights. Pumping, or pulsating of the lights is another fault sometimes met with. In arc lighting extinctions and rapid self-re-lighting sometimes occur.

Broadly speaking, faults, save strictly mechanical defects, easily traced by the engineer, are usually due to *defective insulation* or *defective conduction* in the dynamo or its accessories.

A coil in the armature may be burnt, *e.g.*, the insulation charred; the commutator may not have all its sections insulated; there may be conduction, or leakage, between some part of the armature circuit with the iron body of the machine, or the field magnet coils may be similarly leaking. Possibly a small arc has been established at some point by a failure of the insulation, and this may become active or inactive, according to the current or E. M. F. of the machine.

The *periodic faults* are by far the most troublesome to detect, especially those that do not occur at half load, but appear at or near full load. Others again occur at a given speed, and are not to be traced when the armature is moving at any other speed.

The only effective means of localising faults is a system—a comprehensive system—of tests, which will broadly include all faults that have hitherto been observed. Many faults that appear to be electrical are really due to bad engineering.

Tests for Leakage to Ironwork of Machine.—The first and most important condition of the insulation is its completeness with respect to the iron body of the armature or field magnets. For practical purposes the body of the dynamo, *e.g.*, the field magnet framing and base, may be considered one conductor, complete as to conductivity. The ironwork of the armature is also generally in one with the ironwork of the frame, but it is a great advantage to have the iron core work of the armature insulated from the shaft, and therefore completely isolated. Hence, if a leakage occurs from an armature coil, it cannot get further than the core. In making a test of short circuit to the ironwork, therefore, it is not always correct to assume that the armature core is one with it.

The whole dynamo is usually insulated from the earth. If the ironwork be in contact with earth, any leakage from either armature or field coil will cause an *earth fault.*

In dynamo work ironwork fault and earth fault are usually synonymous, and may be considered together.

The testing instrument is usually a simple galvanometer. The source of current is often the dynamo itself, this test being taken while it is run-

ning. If the dynamo be standing, a few accumulator cells are the most suitable. But it is practicable to make fair tests with any of the portable or "dry" batteries now so common. For heavy dynamo work a potential of about ten volts is, however, very generally used. The instruments—galvanometer, &c. —are generally kept at a suitable distance from the dynamo, especially if it be running.

Connect one screw of the galvanometer to earth by a wire to a gas or water pipe, or other convenient "ground"; lead another wire to the dynamo, and, if it be running, giving current, any leakage of that current to the ironwork, and from the latter to earth, can be ascertained by contact of the wire with the frame of the machine. A deflection of the galvanometer would thus show a *double fault*—leakage of coil to iron, thence to earth. If the dynamo be standing idle, connect the testing battery in circuit with the galvanometer. If no deflection is obtained, and whether the dynamo is running or idle, connect battery and galvanometer to earth as before, and make contact with the wire to the ironwork of the machine. A deflection of the galvanometer will indicate that the ironwork is leaking to earth.

If the dynamo is standing, touch the commutator with the wire—a deflection of the needle will indicate that the wire coils are leaking to ironwork. If the machine be a separately excited dynamo, test the terminals of the field magnet also.

If the ironwork be found insulated, a leakage from coils to ironwork can be detected by connecting the galvanometer and battery to the frame, as to earth, and testing by coil contact as before.

A test should be taken by connecting to iron core

of armature, if it be easily accessible, as to earth, and making contact to the commutator segments. Contact to each of those should be made in succession.

It may be pointed out that if the dynamo be running while making tests, it may only be practicable to ascertain earth insulation, and a false conclusion may be drawn from them owing to a fault to earth in some part of the circuit of the lamps, removed from the machine. A fault of this latter kind would cause all lamps *beyond* the leak to burn dimly.

Tests for Internal Broken Conductors.—The continuity of the field magnet circuit is easily ascertained. Make a circuit of galvanometer, battery, and field terminals—*no deflection* will indicate a rupture of the wire, at some point—machine idle. Localising broken armature wire is also comparatively simple. When the coil extremities can be traced, or are known, make a circuit between the commutator bars attached to those extremities (remove brushes meanwhile); no deflection will indicate a break. This break is very frequently just at, or near the point of junction with the commutator.

When the armature winding is not known, and it is impossible to determine the extremities of the coils, the test for a break is not so simple. As a rule the ends of the coils are in connection with diametrically opposite segments. In this case it may only be necessary to make a circuit by touching these segments with the two wires, from galvanometer and battery. If a *weak* deflection is obtained, it may be due to one of two causes, either the insulation material between the segments has become conductive, by impressed copper dust or charred oil—a liability very common in cases of asbestos insulation—or there is a partial

break or broken wire in partial contact within the coil.

When the fault cannot be located by either of these methods the armature wires should be disconnected entirely from the commutator and each other. In doing this numbers should be attached to ends and segments, indicating the connections in re-attaching. *The extremities of a coil* can then be found by touching with the test wires. If there is a pair from which no deflection can be obtained, the assumption is that the fault is in that coil.

A diagram of the armature winding as applied to the particular make of dynamo used should be kept by the attendant, and referred to when any question of a fault arises. This will indicate where to apply the test wires, and may save many disconnections and experiments.

Intermittent contacts between broken junctions are very troublesome. They will generally give a deflection upon being tested, and cannot easily be located, unless they occur at the point of contact with an armature segment. In the case of a small armature an intermittent contact was found in one case by testing each coil, and while the needle of the galvanometer remained deflected setting the armature in vibration by striking the end of the shaft with a *copper* hammer (to obviate mechanical injury). When the faulty coil came under the test the needle oscillated, showing intermittent contact between (as was found) two ends of a wire bent to a sharp angle near to the end of the armature coil.

Burnt-out Coils.—When an armature coil makes, by fault, a short circuit within itself, *e.g.*, does not deliver its current to the lamps, its current will become

abnormally strong ; it will become heated, and finally the insulation will be burnt off. This occurrence is generally amply indicated, unless it be very gradual, by *smoke arising from the armature* and a *smell of burning varnish and cotton.*

But unless in central stations, where the dynamo is constantly watched, a coil generally burns out without being observed, and the attendant is apprised of it by a dimming of the light or by fluctuations.

Short circuits are, however, when a dynamo is looked after, generally detected before burning out occurs. They are not easy to locate, especially in armatures of low resistance. The best way to determine whether a short circuit exists is to *measure the resistance* of each coil in succession ; the faulty coil will then upset the balance of the test by its lower resistance. Measurement or balancing with the Wheatstone bridge, in order to detect faults in electric lighting stations or circuits, receives some little attention in the succeeding chapter, where also will be found some account of the instruments used for ordinary tests.

All the *ordinary* faults that occur in dynamos can be detected and localised by means of comparatively rough and ready methods, some examples of which have been given.

Much sparking at the commutator is generally a sign of overloading, or a short circuit in the armature.

When a dynamo shows much sparking, and begins to heat rapidly, there is usually a short circuit in the leads feeding the lamps, and this should be seen to at once, otherwise the building may be set on fire.

Example of a Rough Test for Leakage to Earth.—

In central station work, where large currents are evolved, the following rough test for detecting leakage or ground fault is very common. Two lamps are connected in series across the terminals of the dynamo. If it be a potential of 100 volts, two 100-volt lamps are used. The connecting wire between the lamps is put to earth. If there is any leakage it will be shown by the lamp connected to the terminal upon whose line the leakage exists becoming brighter each time the earth contact is made. This not only serves to indicate the lead from which the leak is to be found, but roughly, by the brightness of the lamps, its extent. Such a leakage is called a ground fault, or shortly, a ground. This is a very convenient test, not only in respect to earth leakage, but for leakage to adjacent metallic bodies.

Short Circuit or Fault in a Magnet Coil.—If the coil upon one of the magnet limbs should have a partial short circuit, so that the excitation at one pole is greater than at the other, the defect can generally be observed by larger sparks being given at one brush than at the other.

Failure of Dynamo to Excite.—A shunt-wound dynamo will not start or excite upon low resistance. If the binding screws be connected by a short, thick wire, the dynamo will not give a current at all. Similarly, if a line of arc lamps be inserted in the circuit, with their carbons touching, the dynamo will generally refuse to "build up" or fully excite itself to light any of the lamps. For this purpose a resistance coil is frequently inserted in the lamp, which, when the dynamo has fully excited itself is automatically cut out.

Failure to act or excite may be due to the residual

magnetism being too weak. If a series dynamo will not excite when the terminals are connected with a short piece of wire, and the residual magnetism is strong enough, the fault will generally be found in the neighbourhood of the commutator. The brush contact may be bad. The brushes may be partially or wholly short-circuited. The binding screws may be loose, or may be oxidised so as to impede the generation of a current. If the commutator be of the earlier pattern, insulated between its segments with asbestos, it may prove that, pressed hard into the surface of the asbestos, will be discovered a layer of copper dust, or charred (carbonised conductive) oil. Such a cause of short-circuiting of the commutator was once very common, and even now occurs occasionally. In a case of doubt it may be as well to cut out a portion of the asbestos between each pair of segments, so as to expose a clear line of the substance, free from foreign particles.

The leading causes of failure to act in a dynamo are thus short-circuiting or bad contacts.

Repairs to the Armature.

The armature being the moving portion of the machine is more likely to meet with damage than the field magnets or other parts.

Loose Binding.—Taking the case of a drum armature. The wires are generally protected from the effects of centrifugal force, and from being thrown into contact with the ironwork in the bore of the magnet, by binding pieces of steel or brass. This binding is very generally secured by means of tin solder. The tin solder holds very well for a time, but continuous heatings and coolings gradually weaken it

and the binding is apt to come off or lose its effect upon the coils. From this cause, and others, the armature wire may come into contact with the magnet when moving at a high rate of speed, and so cause short-circuiting or weakening of the current.

There are numerous other causes of faults in the outer envelope of the armature, such as substances falling between it and the magnet, mechanical injuries by careless handling, and so on. In most cases such external faults can be easily rectified. If a wire is laid bare let it be lifted by means of a bone chisel, and, after being treated with a coating of shellac varnish, wound closely around with silk tape, covered by another coating of varnish. After repair the wire must be pressed quite into its original position and varnished a third time to give it adhesion to the adjacent wires. If the binding wire be loose it must be taken off and replaced by fresh, taking particular care in re-soldering that no drop of the molten metal be allowed to fall between the wires.

A broken wire which is usually too short to re-connect by making a joint is most effectively treated as follows: Strip both ends at the break and clean by scraping. Tin them lightly with the copper bit. Cut an inch of brass or copper tubing large enough to slip tightly over the ends, moisten the interior of the tube with soldering fluid, place the two ends therein, and with a drop of solder upon the soldering bit, fuse all together. Clean off and cover carefully with silk tape and varnish.

Repairs of a more extensive nature, such as re-winding, or placing a fresh coil upon a drum armature, are generally intrusted to the dynamo builder. For re-winding it is always best to send the armature

to the actual maker of the machine. Repairs to disc armatures, and all such as have bobbins and coils easily removed from their cores or pockets, are more easily carried out. In such cases fresh coils can generally be kept on hand and slipped on when required. In re-winding a coil upon a "ring" armature, the wire is generally carried in a shuttle, and threaded out and in so as to encircle the ring the requisite number of times. *The number of turns* made by the original coil should be accurately observed, and the same gauge of wire used. Each turn must be drawn tight, and proper insulation applied, with plenty of varnish throughout.

A neat wire splice can be made in a coil by scarfing —or splicing—each end, and filing it rather smaller than the body of the wire; tin the faces of the splice, and solder closely together; file off clean, making the joint rather smaller in the middle than at the ends of the splice; bind it round tightly with a single layer of fine brass wire; tin the whole, and clean off. Insulate as before.

Binding an armature, or re-winding a "reel" coil, should be done by placing the armature or coil between the centres of a lathe. In the re-winding of the Edison type of field magnet, and in several other patterns, the lathe is the most suitable means of rotating the part to be coiled.

Wet Dynamo dried by Steam.—In a recent case, when, by a flood, several dynamos were submerged, they were afterwards completely restored to activity by being dried by steam. The dynamos were covered with tarpaulins, and the steam, at high pressure, applied beneath. After several hours of this treatment, it is said the machines were hot and dry

enough to very shortly restore the insulation, and did not suffer in any way by their bath.

Hints to Accumulator Attendants.

The dynamo attendant is generally, in small installations, required to take charge of a battery of accumulators. Indeed, in most isolated or private instances of the introduction of the electric light, the dynamo is only run throughout the day, the accumulators serving to maintain the supply during the hours of lighting. Hence, most dynamo attendants are required or expected to know how to start and manage these secondary batteries. The following hints and suggestions, derived from practical experience, may be of service to the reader:—

The best position for accumulators is in front of a large window, where plenty of light can pass through the cells, and where the attendant can pass completely around them. These facilities for examination are soon found to be of the greatest service. The cells should be of glass, say of the E. P. S. type, than which there is no better cell. They should be raised to a convenient height from the floor upon a dry wood bench; if possible, covered with several coats of a good varnish, especially the top.

Insulating the Accumulator is generally effected by placing under the four corners of each cell the little porcelain cups, filled with resin oil, generally sold with secondary batteries. To preserve the insulation, no liquid should be spilt about the bench, everything should be kept clean and dry. When accumulators are put away in dark, dirty basements and cellars, they cannot be expected to work well. If possible, each cell should be raised above the bench upon a slab

of thick (pavement) glass, supported at its ends, so as to allow the light to enter below and facilitate insulation.

Starting and Charging an Accumulator.—For 50-volt incandescent lamps not less than 26 cells will be required, arranged in series. This will give an electromotive force of over 50 volts, allowing a margin for loss in leads. Twenty-six cells will be required for one or more lamps, and 50 cells in series will be required for the ordinary 100-volt lamps. For large numbers of lamps more than one battery of cells, connected in parallel, will be required to generate the amount of current called for.*

When a battery is first set up, and the interiors of the cells quite freed from straw and dust by means of a hand-bellows, it should be connected.

The *brown* plates are the positives. The *grey* plates are the negatives; the grey plates are the smaller. In placing them in the cells they should be carefully handled. The plates are put in, of course, alternately—positive, negative, positive, negative, and so on. The negatives should project equally upon each side so that the positives may be firmly held by the rubber plugs. If the plates have been put in correctly there will be a disconnected positive lug at one end and a disconnected negative lug at the other—of each cell. The cells are connected together, positive to negative, throughout, leaving two opposite lugs, one at either end of the battery. If two batteries have to be used the two positives and the two negatives are to be connected together, making two batteries of an equal number of cells working in parallel.

The *positive* (or brown plate) terminal—generally painted *red*—is intended to be connected to the posi-

* See also "Reserve Cells, p. 51.

tive pole of the dynamo; the negative (or grey plate) terminal—generally painted *black*—to the negative pole of the dynamo.

It is assumed that the attendant understands that the accumulator or storage battery is only of use as a reservoir, or magazine, for storing up the work of the dynamo for use while the dynamo is not running, and that it must be charged and discharged alternately.

Charging.—Before charging the accumulators, if it be in a new station and the capabilities of the dynamo and engine have not been tested, it will be necessary to ascertain both. The attendant should be very sure, by means of a preliminary run of at least a day, that the machinery is to be depended upon before attempting to charge the accumulator. It must not be charged partially and then left for a time. Such a course leads to the rapid destruction of the plates by an action known as sulphating. For the E. P. S. accumulators a run of 36 hours is generally considered requisite, without cessation, upon first charging.

Before connecting the dynamo to the accumulator it may be advisable to test the direction of the current according to the rule given at p. 25.

Do not place the acid in the cells until the last moment before connecting to the dynamo.

The solution is made up by pouring a good quality sulphuric acid into pure water until a specific gravity of 1·170 is shown by the Twaddle hydrometer after proper admixture. The solution should stand to cool before being placed in the cells. Each cell is filled until the plates are covered to the extent of half an inch. Each contact should be examined and tightened up before starting.

The dynamo should either be shunt-wound or separately excited. It must give an E. M. F. of 2·5 volts per cell—say at least 60 volts for a 26-cell accumulator. The first run should not on any account be for less than 12 hours. An automatic cut-out must be used to obviate a back rush of current from the battery if the dynamo should, by any reason, cease working.

The charging must commence immediately after the solution is placed in the cells. If it be delayed, sulphating, or the transformation of the lead plates into lead sulphate, will set in. The same will occur if the first charge be only for a short time. The cells should never, and cannot without certain loss, be left only partially charged and idle.

If it be possible, let the dynamo work upon the battery until the charging is complete, which is indicated by the *milky* appearance of the solution. A great deal of gas, in bubbles, also is given off by the cells before the charging is complete. The bubbles of hydrogen are large, rise into the air and burst, wetting everything near with spray. The oxygen bubbles are smaller and less harmful. Plates of glass are very useful to place over the cells while approaching full charge, but the terminals, or connecting lugs, must be wiped free from moisture occasionally. The moisture will of course collect more copiously under the glass.

When the charging is complete the solution will not only look white, but the hydrometer will show its specific gravity to be at least 1·195. This is a sure test of a full charge. In this, as in every test affecting the charge of the battery, the small voltmeter described at p. 59, should be used.

In subsequent charging make sure of the follow-

ing :—That the dynamo is running and is excited (its field magnet circuit closed) before switching on the battery. The battery must never be fully discharged, so that a certain current will be generated by it if not opposed by the stronger current of the dynamo. See that the dynamo is switched off before being stopped.

When the accumulators are switched on to feed the lamps the fall in the store of electricity in its plates can be very accurately noted by means of the hydrometer, the specific gravity falling in direct proportion. The attendant will soon, from experience, learn to fix in his mind the amount of current that has been taken out of the accumulator by means of the hydrometer. He will thus be able to determine very nearly how many hours he must run his dynamo to again fill the cells. The gravity should be taken every time before re-charging.

The rate of discharge is calculated from the number of plates in a cell. It is approximately 4 ampères per positive plate of the size designated "L" (E. P. S. type). Thus, a cell containing 15 plates will discharge at the rate of from 24 to to 30 ampères. The accumulator should never be discharged rapidly or upon short circuit. It deteriorates very rapidly under such treatment. A table of the safe rates of charge and discharge generally accompanies an accumulator.

Neither engine nor dynamo should occupy the same room as the accumulator—the acid spray would prove injurious to machinery.

Working Hints.—Agitate the liquid in the cells occasionally, especially during charging. This will prevent the acid from forming in a layer either above or below, and attacking the plates. A little very dilute ammonia kept in shallow open vessels near the

accumulator will obviate the nuisance of the acid spray. Do not approach the accumulator with a naked light while nearly charged—the hydrogen given off is apt to cause an explosion. Keep all shelves, supports, insulators, cells, and connections dry and clean. Make up for loss by evaporation by adding water only. Soft water is better than limey, hard water. If a cell in the battery fails to charge fully and is yet clear while the others are white, cut it out and connect across the gap with a piece of cable, properly connected.

Sulphating may be obviated in a great degree by the use of a soda solution, made up as follows:—To a quart of strong solution of common washing soda add slowly, during agitation, 12 fluid ounces of strong sulphuric acid. This should be added to the cells in the proportion 1 part in 25. Sulphating may be obviated by keeping the battery as fully charged as possible. Do not let it lie for days in a half charged condition. If the cells are to be left for some time without working they will take no harm if first fully charged and the insulation, &c., left in good order. The attendant must always have at his hand the hydrometer, a thermometer, and either the simple volt indicator sent out with accumulators, or a standard voltmeter. With those three instruments he can ascertain beforehand which cell is likely to prove faulty.

A *faulty cell*, as before stated, should be at once removed. It is of considerable importance to be able to detect a weak or failing cell before it has had time to destroy itself. It is necessary to maintain all the cells in the accumulator as exactly alike as possible, for if there should be a weak cell the strong ones on

either side will rapidly run it down and even reverse it, charging it the wrong way. By means of the voltmeter the condition of the cells can be noted, and any considerable fault detected, but the *temperature* of the cells is regarded as a far more reliable test. All the cells in a battery heat more or less, both while charging and discharging, but *a faulty cell will be warmer than the others*. It will usually emit a hissing sound, louder than the others. The thermometer should therefore be at hand to test temperature, cell by cell, daily. A faulty cell should be emptied of its liquid by means of a siphon. A yard of rubber piping, filled with water, and pinched at either end until one of the ends has been placed below the liquid of the cell, the other hanging down towards the receiving vessel, will be found a ready form of siphon. The liquid should be filtered; the plates should be washed and examined. If they are bent, straighten them, being careful not to damage the plugging. Damage to cells is generally due to *short-circuiting*. Plugs of the lead oxide may fall out of their places in the plates, and short-circuit one or more of the pairs. The importance of placing the glass cells so that light can pass through them, for observation, cannot be too strongly urged. A plug, if it should fall out of its place, may be removed with a pair of hard-wood tongs, or may be made to fall harmlessly to the bottom by a little pressure. There should be enough space between the plates to ensure loose plugs falling to the bottom without short-circuiting the plates.

By way of instruments and accessories the attendant of a large accumulator should be provided with an ammeter, for showing at any time the rate of dis-

charge and the state of the current generally. A bell-alarm, to ring when the rate of discharge is above the normal, to be kept in the circuit. "Excess indicators" of this kind are now to be obtained commercially. They generally consist of certain strips of metal, so fixed in a stand that, upon the current exceeding the safe limit, the heat evolved in the strips causes them to bend and make contact with an electric bell circuit. The bell is generally put in the circuit of one of the accumulators. The distance between the contacts being adjustable, any unsafe amount can be readily provided for. A *cut-out* may of course be used instead, but there is the disadvantage in this that any excess of current, upon acting upon the cut-out, will extinguish the lights.

An automatic switch, for acting upon the circuit while charging, is a valuable accessory. These act by closing the circuit when the dynamo is supplying a current strong enough to charge the cells; but should the current become weak, or other fault occur, the switch will open the circuit and so prevent the accumulator from reversing the dynamo. It may be pointed out that this form of cut-out is especially recommended for use with a series-wound dynamo.

While both charging and discharging it is generally necessary to vary the number of cells in circuit. This is effected by the switch-board, which, as supplied for accumulator installations, is usually provided with switches for "charging," "discharging," "dynamo in," "dynamo out of circuit," &c. In many installations the accumulator is used in conjunction with the dynamo, or more commonly a portion of it. Thus, if anything happens to the machinery, the reserve cells

can be switched in, and the absence of the dynamo not noticed.

Leads and Contacts to the Accumulator and Dynamo.—A great deal of waste often takes place by the use of leading cables too small, but more often by bad contacts. Let the lead be amply large enough, and well insulated. Wherever there is a connection that cannot well be soldered, observe, after screwing down the terminal upon the cable and removal, what *surface of contact* exists between the two. The "pinch spot"

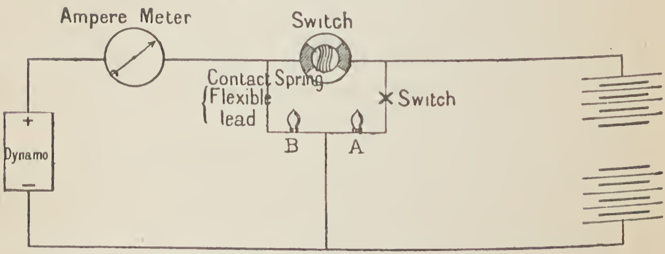


Fig. 10.—Device for Switching Dynamo in Parallel with Accumulator.

will show this. Let the contacts be large, and all such screws protected from oxidation.

Switching-in Dynamos at right instant.—On this point a letter from Mr. Melhuish, of Vienna,* describes an ingenious device of his own for overcoming the difficulty of estimating the right time for switching-in the dynamo in parallel with the accumulator. He says, "Perhaps others as well as myself have experienced some little difficulty in putting the charging dynamo on to the accumulator battery exactly at the right time, *i.e.*, just when the E.M.F. of the machine is equal to the E.M.F. of the battery; and I have

* *Electrician*, vol. 20, p. 451.

often seen heavy sparking at the commutators and the armatures probably strained by the connection being made too early or too late. Some of the automatic appliances made for this purpose get over the difficulty to some extent, as they are generally set to make the contact when the volts on both sides are approximately equal, but such apparatus are costly at best. I found using a voltmeter also not so convenient as the very simple plan shown diagramatically in the accompanying sketch, Fig. 10. The lamps, A and B, are first selected as giving the same light with the same E.M.F. The lamp A, it will be seen, is lighted from the accumulators, and B is connected with the machine. If now the machine is started B will gradually become bright as the speed increases, and by watching until the light given by the two lamps is equal and then closing the switch, the circuit is made without the least sparking at the commutator of the dynamo, and without throwing any strain whatever upon its armature; for if a double-ended current indicator be placed in the circuit it will be seen that it remains at zero with scarcely a tremor, even when closing the switch."

This plan appears preferable to the use of an automatic instrument, for it is doubtful if it be possible to so adjust an automatic switch as to remain in the same condition month after month, in daily use.

Reserve Cells.—As an accumulator is discharged there is a fall in the potential, but it is so slight that two or three cells, at most, held in reserve suffice to restore the full E.M.F. These also are arranged so that they may be switched in one by one as required. A fall of five volts in a hundred affects the brightness of the lamps.

CHAPTER III.

SWITCH-BOARD AND TESTING WORK.

Running Series or Shunt Dynamos in Parallel.—A good deal of difficulty has been encountered in the running of alternating dynamos (or rather in the switching in) in parallel, especially in public lighting. This has been mostly overcome, however, and it is quite commonly done at all large stations. But the working of constant current machines has been effected in parallel from the first days of electric lighting, probably as early as 1881, and presents few difficulties.

But if a continuous current dynamo is feeding a number of lamps; and if the load upon it begins to be too great, by the switching in of additional lamps, it will not be practicable to merely switch on another machine, even if running at the same speed. Such a course would result in a great electrical strain being put upon both machines, in great overheating, in burning of the commutators and brushes, in dimming or putting out the lights, and, finally, the possible reversal of the fresh machine and the running of it as a motor, if it happen to be the smaller.

The new dynamo must first be "built up," as it is sometimes termed; that is, worked upon an artificial resistance until it is giving a current and pressure at least as great as half the load of lamps upon the working machine.

There are other methods of switching in a new dynamo, but not generally practised, and as the preliminary loading plan is so simple and practicable we will confine our remarks to it alone. In the earlier days of the electric light a bank of lamps, equal at least to half the probable load upon the working dynamo, was provided, suitably connected, and in view of the attendant. The new dynamo was started and worked upon the "bank" until they showed full brightness, compared with a lamp fed by the first machine. The switch was then at once brought into play, and the two dynamos put in parallel upon the main leads. Immediately afterwards the artificial bank of lamps was switched off the new dynamo. Each machine would then take half the load; the first machine would begin to cool down, and the lamps would maintain their brightness.

Artificial resistances in the form of lamps are not now so generally used. Such a course is unnecessary, where the attendant is provided with ammeters and voltmeters. It is more usual to employ either carbon or iron resistance frames. The iron frames are usually either in the form of iron wire wound spirally upon iron tubes, with asbestos separating insulation, or in the shape of zig-zag courses of hoop iron, exposed to the air. It is not of material consequence what form the artificial resistance takes.

Before starting the new dynamos the volts and ampères given by the working machine must be observed. This is usually done by keeping the instruments in the circuit, so that the load upon the machine can be observed at any time. Similar indicators must also be placed in the circuit of the fresh machine, and its working continued upon the artificial

resistance until the volts and ampères given by it agree approximately with those upon the working dynamo. The two machines are then put in parallel, and the artificial load at once taken off, as before explained.

For small installations, not provided with many instruments, the simple method of getting the potentials equal before switching in, explained at p. 50 as applicable to accumulators, will be found very useful.

To prevent overloading many stations are furnished with current registers, so arranged that, after the manner of an "excess alarm," a bell begins to ring as soon as the current becomes abnormal. These can be adjusted beforehand to go off at any predetermined load, and obviate any overheating or injury to the working machine.

Alternating Current Dynamos in Parallel.—To effect the running of alternators in parallel without injury to the lamps, or other inconvenience, is not quite so simple as the working of uni-direction machines together.

It may be well to explain that alternators work according to a "phase," a given predetermined number of which are completed in a minute or second, as the case may be. The phase or wave is frequently symbolised by a curved line, ∾ . The number of these per second is known as the rate of alternations, or the periodicity of the dynamo. In Europe the makers of alternators run their machines rather slower than American makers; thus many European alternating dynamos give only 80 to 100 alternations or waves per second, while Westinghouse's American alternator gives as high as 267 per second.

Synchronising, then, of the phases of two dynamos to work in parallel cannot be effected unless they are of the same period and moving at the same speed.

It is generally known that it is easier to work alternators in parallel as their rate of alternations is slower, or, in other words, the switching on is more simply effected, with less liability to disturb the lamps.

If a fresh alternating dynamo, moving at the same speed, and giving the same rate of alternations, be switched at any time into the working circuit of another, a violent jumping of the light, with possible extinctions and re-lightings, will generally occur. This will go on until the two dynamos have worked themselves into the same speed, and are in perfect synchronism. It will be observed that they quickly pull each other into unison.

Such an occurrence would not only be unsuitable to public lighting, but would *rapidly destroy the lamps*. The life of a lamp would, under this treatment, be reduced very considerably, and many lamps, failing to stand the strains, would break altogether. This is not, of course, the only objection to the indiscriminate throwing on of a fresh alternator to a working circuit. The insulation of the machines themselves would probably suffer just as much as the lamps, and there are other objections. Hence the only practicable method is to determine beforehand that the two machines are in perfect accord. Switching on is then attended with no disturbance in the working circuit.

Practically the first dynamo is simply run until its volts and ampères agree with those of the working dynamo. When *perfect* accord occurs the connections are made *instantly*. If well done scarcely a flicker in

the lamps will ensue. It is generally effected by means of both instrument observations and one incandescent lamp. A small auxiliary switch places the fresh dynamo parallel with the working machine through one lamp only. This lamp is carefully watched. It usually flickers or dims and brightens frequently before a perfectly steady moment occurs. As soon as the lamp is at full brightness, and is quite steady, the main switch is at once thrown in, bringing both machines upon the same main. If there be any tendency of one alternator to fall out of phase with the other more work will be thrown upon the faster engine, and a balance of half and half is thus almost instantly obtained.

Accumulators and Dynamos in Parallel.—Storage batteries are, of course, only used in connection with continuous current machines. They are being largely employed in central station work, and there has not been found any difficulty in operating them upon mains and feeders in conjunction with dynamos. But in balancing an accumulator to feed in parallel with a machine the use of a rheostat, or resistance, is not required for the accumulator. It is usual to switch in cell after cell until a balance of power is obtained. Again, the simple test lamp device, described at p. 50, may be employed for indicating in place of more elaborate instruments.

Central Station Time and Current Curves.—The use of these is becoming very common. At each central station is kept a table showing at a glance the probable consumption of current at any hour in any given month of the year. This arrangement has led to such a system that the switching attendant can tell almost to a few minutes when to look for an abnormal

current from his working dynamos, indicating the necessity for a fresh machine in parallel.

Working Indicators for the Switch Room.

It is curious that scarcely any of the instruments that have been hitherto employed for measuring purposes in the laboratory or class-room have been found useful for the practical work of the dynamo room. This fact has given rise to the production or invention of a goodly number of indicators especially designed for the practical working of installations or systems of public supply, and as most of them are new, or have only come into use within the past year or two, we propose to acquaint the reader with a sketch of two or three of them in the hope that this preliminary information may prove useful to him in employing the instruments themselves. We can only, however, notice a few of the most successful within the limits at our disposal.

Cardew's Patent Voltmeter depends for its action on the expansion of a high resistance wire due to the heat produced by the passage of a current, and is, therefore, absolutely free from the errors due to neighbouring currents and other causes which sometimes exist in other forms which depend upon magnetism for their action. It is said to be the only voltmeter that is self-compensating for temperature and will give the same reading in summer and winter. So far, the Cardew instrument has been chiefly used for alternating currents, but is said to be quite as effective under continuous currents.

The external appearance of the instrument may be observed upon price lists, and merely shows a long tube, carrying at one end a large dial, with a light

finger moving over a circular scale graduated to volts and fractions thereof.

The interior of the instruments, as made according to the "1890 pattern," is shown in Fig. 11, where the general arrangement for magnifying the movement due to the expansion of the wire is exhibited. It consists of a series of wheels, or bearer pulleys, usually of bone, set in jewelled centres, with a hair-spring for eliminating "back-lash." The fine wire is carried from the small central pulley away on both sides to the bottom of the tube and back again, so that although the expansion obtained is that due to only half the wire in use the mechanical strain on the wire is halved. A safety fuse is inserted to save the working wire in case of an excessive E.M.F. being applied to the terminals, but care must be taken in using the instrument not to lift the brushes of a dynamo or produce a sudden difference of potential which might

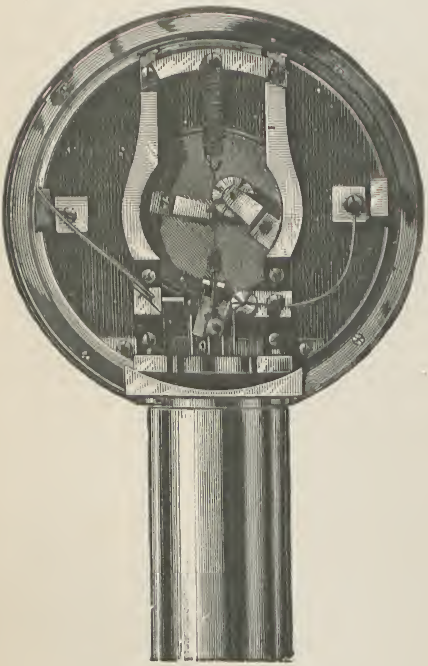


Fig. 11.—Cardew's Voltmeter.

destroy the working wire before the fuse could act. The wonderful accuracy of this instrument, within certain useful ranges, is becoming well known. It is made generally in two patterns, vertical and horizontal, in sizes ranging from 10 to 30 volts, and similar ranges, three other sizes up to from 40 to 150 volts. The

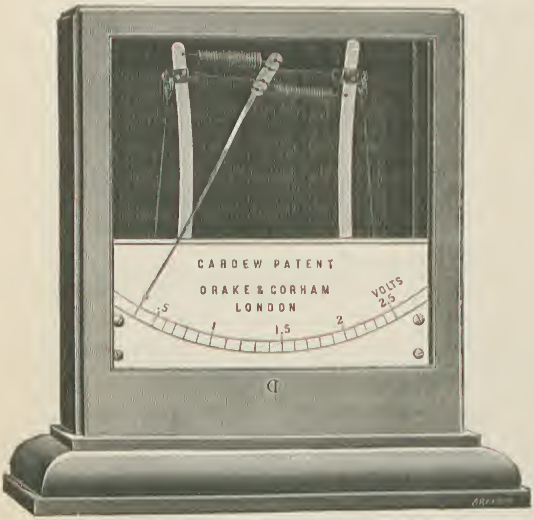


Fig. 12.—Accumulator Voltmeter.

horizontal tube pattern instruments read up to 120 volts. Messrs. Drake & Gorham are the owners of the patent.

Cardew's Accumulator Voltmeter.—An accurate voltmeter, reading from 0 to 2·5 volts has hitherto been a very difficult one to obtain. In the Cardew cell tester, which will actually read within these figures, we have an accessory indispensable to the user of storage batteries. At p. 47 we gave reasons for the extreme care

with which accumulators should be tested for condition, *cell by cell*, at frequent intervals. Although the thermometer will give timely notice of any short circuit in the cell, or other cause that might give rise to heat, there is nothing so certain as a test of the E.M.F. of the cell. The instrument, Fig. 12, is extremely simple, depending as it does upon the slight expansion of a highly resisting wire in two parts, strung in a tense condition between two insulating horns. The wire controls the movement of a pointer so pivoted as to magnify the expansion. The little

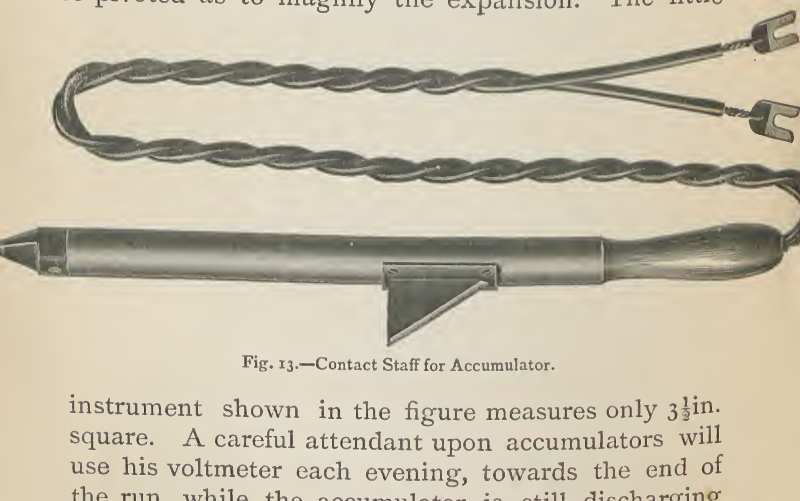


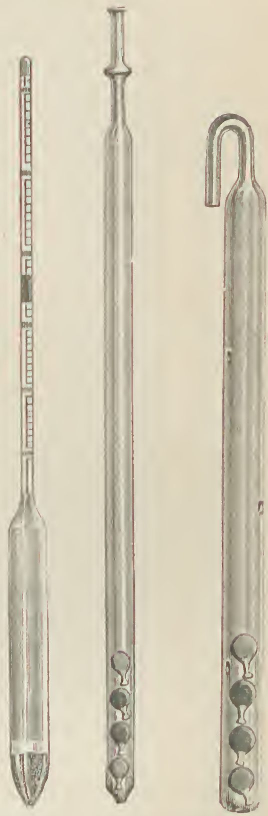
Fig. 13.—Contact Staff for Accumulator.

instrument shown in the figure measures only $3\frac{1}{2}$in. square. A careful attendant upon accumulators will use his voltmeter each evening, towards the end of the run, while the accumulator is still discharging upon the lamps, when the lower E.M.F. of any weakly cell can be the more easily detected. But in addition to the use of the voltmeter for detecting incipient faults in the cells it is the proper indicator of the state of the battery while charging. When the cells attain to an E.M.F. of 2·5 volts they are *very nearly* fully charged, and in discharging they should

never be allowed to fall below 0·5 volt for reasons explained in the remarks upon accumulators, p. 46.

For making connection with the poles of the cells a useful form of contact maker, Fig. 13, is issued with the small voltmeter. It is only necessary to touch, for a moment, the two poles.

Accumulator Hydrometer Instruments.—While on the subject of instruments for testing accumulators note may be made of the kinds of hydrometers commonly employed by attendants of storage batteries. Fig. 14 represents the usual form of open scale hydrometer with a flattened bulb. It scales from 1·075 to 1·300, an ample range for accumulator work, according to its height floating in the solution. The later form of "bead" hydrometers, Figs. 15 and 16, contain four coloured glass beads, which float at the following densities respectively 1·1050, 1·170, 1·190, and 1·200. These are, of course, more easily read in a poor light than the scale instruments. Fig. 15 is made much longer, for use in storage cells contained in teak boxes, as used aboard ship, and is known as the ship hydro-



Fig, 14. Fig. 15. Fig. 16.
Hydrometers.

meter. The instrument is adapted to be passed through the vent hole in the cover of the box, and to withdraw a sufficient quantity of the solution to enable the beads to float. In order that the liquid may not escape, the finger is placed over the opening in the top of the tube. This form is useful also in indicating the level of the solution in the cell. The "Holden" type hydrometer, represented in Fig. 17, as in use in a glass cell, is also largely employed on account of the ease with which its indication can be read. The scale as shown is separate, and set with its point touching the liquid.

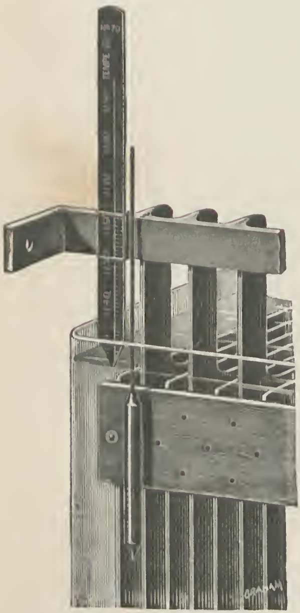


Fig. 17.—Holden's Hydrometer.

Magnetic Voltmeters.—A considerable number of fairly accurate voltmeters, depending for their action upon a permanent magnet, have been introduced of late. Messrs. Ayrton & Perry's is one of the best of these, and is too well known to call for detailed description. There are, however, in certain situations several objections to permanent magnets, the most forcible of which is doubtless the tendency of such a magnet to change in strength, or weaken with time. Such a fault calls for re-adjustment of the instrument at frequent intervals, with all the trouble of having to make or employ an absolutely

accurate "standard" cell, giving a known voltage. This re-adjusting is generally known as calibrating.

To Calibrate Ayrton & Perry's Voltmeter.—It may be useful to owners of these instruments to possess a ready rule for re-adjustment. In both the simple and commutator instruments the adjustment by which the deflections are rendered direct is made by moving the galvanometric coil from a stronger part of the field into a weaker part, or *vice versâ*. The coil is supported by two screws, and by means of nuts it can be moved as above described. On unscrewing the base-board the magnet and coil of the instrument are exposed, and the adjustment can then be made. To calibrate the commutator voltmeter turn the commutator to parallel, and send a curent from a standard cell of known E.M.F. through the instrument; a deflection, D, will be obtained.* Pull out the plug of the resistance coil, and a new deflection, d, will be given. If E. is the E.M.F. of the standard cell, then the difference of potential at the terminals of the instruments $= E\frac{D-\mathrm{d}}{\mathrm{d}}$ volts for deflection D, and 1° gives $E\frac{D-\mathrm{d}}{D\,\mathrm{d}}$ in parallel, or $10\,E\frac{D-\mathrm{d}}{D\,\mathrm{d}}$ volts in series. The adjustment of the coil can be made until the desired value per degree is obtained. Although a Daniell cell, giving as nearly as possible, when in zinc and copper sulphate 1·07 volt, is frequently used for calibrating, the result cannot be accurate reading. It is much more satisfactory to use one of Mr. Latimer Clark's standard cells, the employment of which is becoming common among electrical engineers. The E.M.F. yielded by this little cell is accurately 1·435

* A battery of several such cells is usually employed in calibrating.

volts at ordinary temperature. The Clark's cell should never be allowed to work through any resistance less than 1,000 ohms.

Paterson's Electro-Magnetic Voltmeter.—For ordinary work this voltmeter has proved itself very useful. It is at least free from most of the objections urged against permanent magnet voltmeters, and is said to be constant, calling for no re-adjustment. On the other hand the magnetism is got by the setting up of a current, and although this would only introduce a trifling error in a case of considerable E.M.F., it might give rise to a slight drop of potential in the case of delicate readings. The instrument is handy, and not too high in price, with a register accurate enough for every day use. Fig. 18 represents the external appearance. The usual permanent magnet is replaced by a slender electro-magnet, acting upon an indicator in the usual way. It is made to give ranges of from 0 to 5 volts, from 2 to 50 volts, and so on up to 200 volts. By means of extra resistance coils the range of the instruments can be multiplied by 2, 4 or 8.

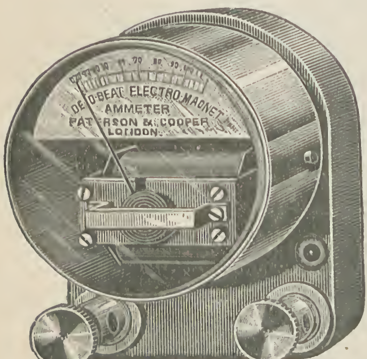


Fig. 18.—Electro-Magnetic Voltmeter.

Sir William Thomson's "Steel-yard" Gravity Voltmeter is becoming well known to working electricians. It is one of the simplest and most effective in use,

consisting as it does of a high resistance coil, in the form of a cone, within which is suspended a short conical piece of soft iron, balanced upon the short end of the steelyard. The connection of the coil to the poles of an electric source causes an attraction of the stumpy piece of iron further into the coil, and a corresponding movement of the steelyard indicator over its scale. Sir William Thomson's new direct-reading vertical scale voltmeter is likely to have extended application for the finer work of the testing room. The same eminent electrician's electrostatic voltmeters, and his recent Centi., Deci., Deka., &c., ampère balances are likely to meet a demand for highly accurate ampèremeters.

A description of Siemens' Electro Dynamometer is scarcely necessary.* Both that and the standard voltmeter introduced by the Edison-Swan Company, as devised by Messrs. Gimmingham & Fleming, are becoming fairly common in collections of electrical test instruments.†

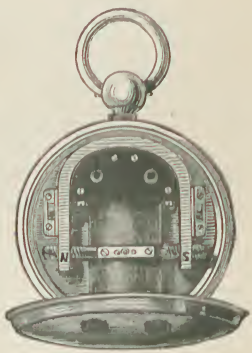


Fig. 19.—Pocket Voltmeter.

Pocket Voltmeter.—As illustrating the extreme of portability the pocket voltmeter, represented in Figs. 19 and 20, will prove of interest to electricians whose avocations take them away from the more important instruments, which must be kept in the test room, or, at best, cannot be carried in the pocket like a watch. The little volt-

* See "Electric Light," p. 331.

† See a paper read before the Institute of Electrical Engineers, Nov. 25, 1887, for a description of the latter instrument.

F

meter shown is fitted with a permanent magnet, in the field of which is placed a small galvanometric coil, the terminals of which end in two insulated plug holes at the edge of the case. The indicator axis is carried through the face, and terminates in a light style, moving over a graduated scale. The pocket voltmeter is made to read in ranges, from 0 to 10 volts, and so on, up to 80 volts.

Messrs. Ayrton & Perry's Spring Voltmeter and

Fig. 20.—Pocket Voltmeter.

Ammeter has only very recently come into use, but it is likely to supersede many of the more common forms of electro magnet voltmeters. It consists essentially of a coil of wire, acting as a "sucker" coil, the core being a tube of soft iron. To the tube is attached the lower end of a kind of constant diameter volute spring, which carries a pointer on its upper end. Upon the coil being connected to the poles to be tested, the coil excites a down-pulling force upon the

soft iron tube, thereby sensibly extending the spring, and causing its upper end to rotate a certain distance, carrying the pointer. It is a very useful instrument for practical work, and acts either as a volt or an ampère meter, according to the resistance of the coil used.

Ampèremeters for Station Work.—Most of the instruments already spoken of as adopted for the measurement of E. M. F. (voltmeters) can also be used, with slight alteration, for measuring current. As a rule, an ammeter is simply a voltmeter with a coil of lower resistance. At many central stations rough, large ampèremeters are put up, composed of a coil of insulated wire, having a freely-moving core of iron or steel balanced within it. The core carries an indicator, or is attached to the short end of a long steelyard, moving over a scale. The scale is usually a rough one, made to correspond with the movements of the indicator. Such a makeshift instrument has frequently been found to preserve its accuracy longer than many more pretentious ampèremeters. Ammeters for installations or central station work are frequently graduated not to ampères, but to lamps, and are adapted to show the number of lamps in the circuit at a glance. Such a system cannot be recommended. It is well known that lamps vary greatly in their consumption, and any instrument graduated to them can only give a rough approximation to the actual current passing.

Whenever makeshift or doubtful instruments are to be used they should be carefully standardised first by means of the torsion dynamometer of Siemens. The ampèremeter devised by Messrs. Fleming & Gimmingham, now issued by the Edison-

Swan Company, and spoken of at p. 65, is likely to have an extended application. But the introduction of commercial ampèremeters, dating as it does back only a few years, has not yet led to the general adoption of any particular system—each electrician chooses or devises for himself.

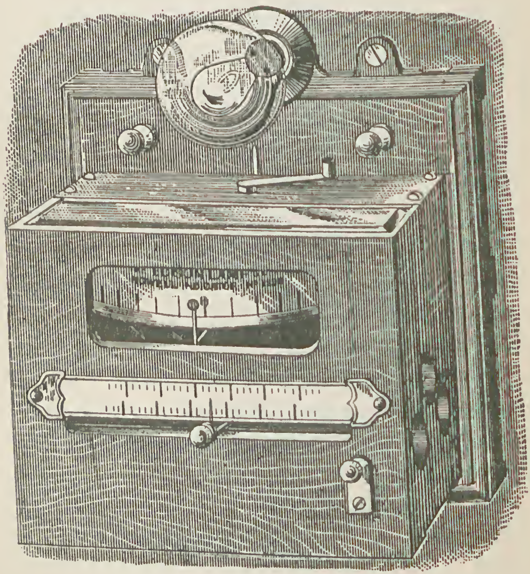


Fig. 21.—Edison-Howell Lamp Indicator.

Edison-Howell Lamp Indicator, as used on the commercial circuits in America, is represented in Fig. 21. A magnetic needle is employed as the indicator. It remains at "zero" (that is, in this case, the centre of the scale, indicating the "balancing point" or position of equilibrium when set to the exact voltage required upon that circuit), and is only caused to

deviate either way by any abnormal fall or rise in the potential or current. In principle it depends upon the great variation in the resistance of carbon as the filament of a lamp, due to any change in the temperature. A rise of temperature is accompanied by a fall of resistance in these lamps. In order to utilise this fact use is made of the principle of the Wheatstone's bridge, as indicated in the diagram (Fig. 22). The circuit to be indicated is made to pass a portion of its current through the incandescent lamp. The amount

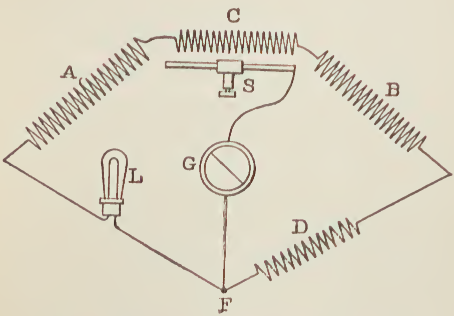


Fig. 22.—Diagram of the Lamp Indicator.

of this current is determined by the E.M.F. or pressure in the circuit, and varies with the pressure. The temperature of the filament varies with the current, as does also its resistance. Thus, by measuring the resistance of the filament (or balancing it) an indirect measure is got of the pressure acting upon it. The marks upon the scale are laid out to indicate the volts necessary to bring the carbon filament to the resistance required, so that the scale gives a direct measure of the E.M.F. in the circuit.

In the diagram L represents a carbon filament

lamp. D is a coil of wire of sufficient size to carry the lamp current without overheating. These two resistances form one arm of the bridge. The other arm is composed of three resistances of wire, A, C, and B, and the galvanometer is connected between the point F and the frame upon which the slide contact S slides. This enables the galvanometer contact to be made at any point of the resistance C. If A, plus that part of C on the left hand side of the galvanometer contact be represented by A^1; and B, plus the part of C on the right hand side of the galvanometer contact be represented by B^1, then when a balance is obtained on the bridge, and no current flows through G, we have $A^1 D = B^1 L$. G is a simple form of galvanometer which indicates the direction and relative amount of the current flowing through it. When the instrument indicator is in zero, no current is flowing in G. If, now, the sliding contact be in the centre of resistance C, and a suitable lamp be in L, on sending a current through the indicator, and gradually increasing it, the resistance of the filament becomes less and less, until, when the desired pressure is acting upon the indicator $A^1 D = B^1 L$ no current flows in G, and the indicator remains at zero with the circuit either made or broken. This position of the sliding contact is marked D, and, if at any time the contact be placed at this point, and the pressure made such that there is no current in G, it is evident that the indicator shows the same pressure as that employed when it was adjusted at that point. The indicator being thus balanced, if the pressure be increased the pointer will move to one side of zero; if it be decreased, it will take an opposite course.

Should the sliding contact now be moved to some

other point, it will alter the values A^1 and B^1, and the pressure will have to be adjusted until the resistance of L is changed enough to make $A^1 D = B^1 L$ again. This position of S, corresponding with the new pressure, may be marked, and in this way can be ascertained the pressures that will balance the bridge with the contact S in any position on the coil C. Thus the scale should be marked for a range of volts. The pressure of the circuit may thus be set at any point that is on the scale, and changing the pressure on the line until the bridge is balanced and the pointer remains at zero, as before, whether the galvanometer circuit be closed or open.

The interior construction of the instrument shows a galvanometer needle carrying a long, light indicator, the terminal point of which is visible upon the upper scale of Fig. 21. A directing magnet is swung upon an axis, accessible from without the case, so that the indicator can at any time be brought to zero. The sliding contact, the indicator attached to which is visible upon the lower scale of the box, has a handle projecting through the case for setting. The coils have a resistance of 90, 257, and 1,000 ohms respectively, and are composed (as to A and D) of German silver wire, and B, partly of German silver and partly of copper; by a known proportion of these the indicator remains balanced at all ordinary temperatures.

Two lamps are usually sent out with each indicator, marked in red and black, corresponding with the red and black marking of the two scales. The object of this is to afford a means of checking the accuracy of the readings by employing one lamp solely for the purpose of comparison, which is used but seldom,

and whose resistance therefore is not liable to variation with time. The other lamp is constantly in use, and any variation of its resistance can be ascertained at any time by comparison with the standard lamp.

If the pressure in the mains rises when the instrument is connected across the wires in use, current will flow across the bridge. This will heat both the carbon filament and the German silver wire, but whilst heat increases the resistance of a metal it diminishes that of the carbon filament; hence the resistance of one pair of arms is increased but that of the other pair is diminished, upsetting the balance and causing the galvanometer indicator to deflect from its position of zero. This test is very delicate, and necessarily so, when we consider that a fall of five volts in a hundred in the working pressure will cause lamps which burn quite brightly at a hundred volts to become very dull. On the other hand, a rise of five per cent. will tend to shorten the life of the lamps. Upon well-conducted systems the pressure upon the mains is never allowed to vary more than one-half per cent. Such close working could not easily be attained by any ordinary means other than the use of zero-indicating instruments such as we have described.

Regulation of the Dynamos to correspond with Balance Indicator.—As we have already ascertained (page 6). the regulation, save in small installations where a compound-wound machine may regulate for itself, is usually effected by varying the exciting current by means of a shunt. The exciting machine field is indeed the point of regulation generally resorted to. It is comparatively easy, by means of a simple resistance frame, to so control this small current that the pres-

sure is kept within the required half per cent. At some stations the speed of the engine is accelerated or retarded as required.

Enough has been said to give some idea of the nature and variety of indicating and regulating instruments employed in isolated and central station plant working.

A few words further, by way of summing up. The general scope of these indicators and controllers may serve to fix in the reader's mind the everyday application of this lately-developed system of regulating electric supply.

Of *Rheostats* it may be said that for practical dynamo-room work they are simply resistances that can be adjusted from little to much at will. They take many forms. For heavy current work large rheostats usually consist of coiled (or otherwise compactly disposed) iron wire, or of hoop-iron, or of carbon-rod; or, for instrument work, the more expensive German silver wire. The practice of controlling by means of a variable resistance, save for small currents, is going out of fashion. At one time, and even now, in isolated plants, the main current was passed through a resistance which was raised to suit the lamps. This was extremely wasteful, and a great step in advance was taken by controlling only the exciting current of the field magnets—in other words, varying the resistance of the shunt. It is of course still more economical to vary the current of the field of the exciting dynamo when a separate exciter is employed. Dynamo *balancing rheostats* are merely resistances having a range sufficient to balance the current of one dynamo against that of another, with which it is desired to run it in parallel. This was formerly, as explained at

p. 53, effected by a rheostat of lamps, or merely a bank of lamps, not adjustable.

The *regulating* part of the rheostat usually consists of a series of contacts, or copper plates, connected in series with successive portions of the iron wire or hoop. By the sliding of a lever over them each one is in turn switched over into the circuit and adds its resistance thereto. They are usually made in the form of a circle for ease in manipulation. It may be accepted as a sign of poor electrical engineering when large rheostats have to be used at all. Their use means waste and bad regulation.

Résumé.—Broadly, then, the instruments used in the dynamo and switch-rooms are as follow:—Rheostats, for regulating the E. M. F. and current of the dynamos; balancing rheostats; potential indicators (voltmeters) for showing at a glance any variation in the pressure upon the leads or mains (*brightness of the lamps*). These usually remain continually in the circuit. Ampèremeters (current meters) used to indicate the *number of lamps on circuit.* This is also commonly kept in circuit, and shows, in conjunction with the voltmeter, the work going on, giving warning of any necessary approaching change. Detectors, for calling attention to ground or earth faults. These take several forms, according to the nature of the work and the potential at which the mains are charged.

Resistance and Insulation Testing.

The "practical" electricity of the schools, class-rooms, and laboratories is frequently so different from the practical electricity of the electric light station that a few hints respecting the taking of resistances appears necessary in the present chapter.

The resistances that most frequently need to be measured are those of the coils of armatures and field magnets of dynamo machines, the resistances of mains or leading cables, the resistances of branch leads and wiring generally in buildings. These are resistance tests only, but they only give half the information generally required. It is frequently still more necessary to ascertain the *insulation* resistance of the coils of armatures and field magnets, and of mains, feeders, branch leads, and wiring generally.

A rough measurement of the resistance of an armature, or field coil, is sometimes taken as follows. It may, of course, be made sufficiently accurate for ordinary purposes by using sufficient care in taking the test. It depends upon the principle of comparing two deflections of the galvanometer, which are proportional to the fall of the potential shown by the insertion of a resistance.

Take a wire measuring over a hundred ohms, and another wire of only a hundredth of an ohm. These can be obtained from, or produced by, the testing set described further on, if not at hand. Connect these in series with an accumulator cell, and the brushes pressing upon the commutator of the dynamo, forming a complete circuit: cell, two resistances, and armature coil. For the test employ, if possible, a delicate reflecting galvanometer; connect it by wires with the two ends of the one hundredth ohm resistance and note the deflection. Remove the wires and apply them to the brushes of the machine, turning the commutator round, sector by sector, so as to get the average deflection. The average deflection produced upon the galvanometer, compared with the deflection got from the one hundredth ohm coil, show at once the

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resistance of the armature coil compared with the hundredth ohm coil; *e.g.*, a deflection of 50° from the armature coil and of only 25° from the hundredth ohm coil would show that the armature coil had as much again resistance as the hundredth ohm coil. A "comparison coil" of any suitable resistance can be used, but when the resistance of the armature is low the hundredth part of an ohm is a convenient standard. The rough coils employed for this purpose are frequently of hoop iron. Strap iron, having a thickness of $\frac{1}{32}$nd of an inch and a width of half an inch, will be found to give approximately one ohm resistance for each 100 yards. The high resistance coil is merely used as a "choking coil" to obviate the passage of an appreciable current by the cell. The setting up of a large current, which would ensue upon using a small resistance, would probably entail a fall of potential in the cell, and an error in the observation.

This simple method is frequently used for measuring the resistance of circuits, its chief advantage being that no instruments are required except a reflecting galvanometer, and only one of the resistance coils—the smaller—need be accurately known.

Testing Box.—But for general resistance measuring a proper "testing set," consists of a Wheatstone bridge combined with resistances in a case, and a testing battery in a separate portable form. The nature of the balancing method generally spoken of as Wheatstone's bridge is well known to students, and since it is elucidated in class-rooms, and may be studied in any standard text-book of electricity, it will be unnecessary to describe it fully here. The class-room Wheatstone bridge, however, is not quite similar to that used by practical electricians, and we

therefore select for description a good form for every-day working purposes.

Fig. 23 represents the general appearance of a testing box, as issued by the Gutta-Percha and Telegraph Works Company, and is especially designed for the use of electric-light engineers.

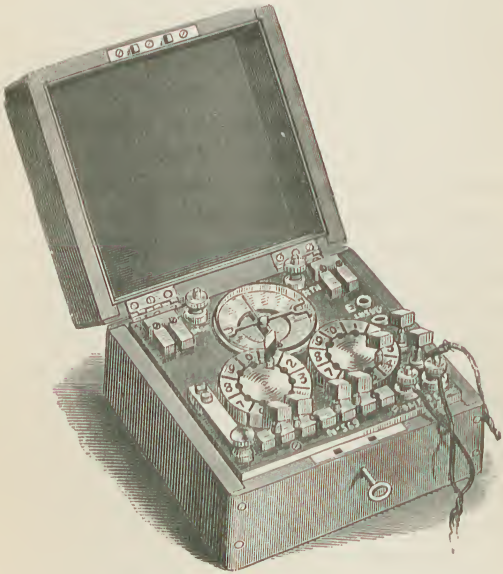

Fig. 23.—Testing Box.

It consists of a Wheatstone bridge with dial pattern resistance coils, capable of measuring copper resistances of from ·01 ohm to 9,900 ohms, a highly sensitive galvanometer, and all the necessary appliances for measuring insulation resistances up to 30 meg-ohms, a galvanometer key, and $^1/_9$th and $^1/_{99}$th galvanometer shunts, fitted complete in a teak-

wood case, the dimensions being $7\frac{1}{2}$ in. × $7\frac{1}{2}$ in. × $6\frac{5}{8}$ in., and weight $8\frac{1}{4}$ lbs.

Such a testing box saves a great deal of trouble. It obviates the necessity for setting up the delicate and by no means portable instruments sometimes employed where reliable tests are to be made.

The battery consists of 30 Leclanché elements of a special portable pattern, contained in a polished wood box 11 in. × 9 in. and 7 in., connected up to terminals in the box, and provided with flexible wires for connection to the test-box.

To take a Conductor Resistance.—Fig. 24 represents the particular arrangement of the resistances, terminals and galvanometer in the box forming the Wheatstone bridge. Figs. 25 and 26 show the connections necessary in taking copper resistances and insulation tests respectively. It may be pointed out that *insulation testing* is daily becoming of more and more importance. The fire offices now insist upon stringent conditions of safety insulation, and it may be accepted as the tendency of the times to provide abundant "safety" insulation as distinguished from purely electrical insulation, which might in many cases be of a comparatively inferior nature and yet, serve the purposes of carrying the work of feeding lamps on from day to day, without much loss.

Reverting to Fig. 24, A and B are Wheatstone-bridge balance coils, and C and D, two dial-form resistances; G the galvanometer, and K the key.

Connect the conductor or the circuit to be tested to the "bridge terminals" on the right front of the box; the plugs connected to the battery wires are to be placed in the "bridge" plug holes in the right of the box.

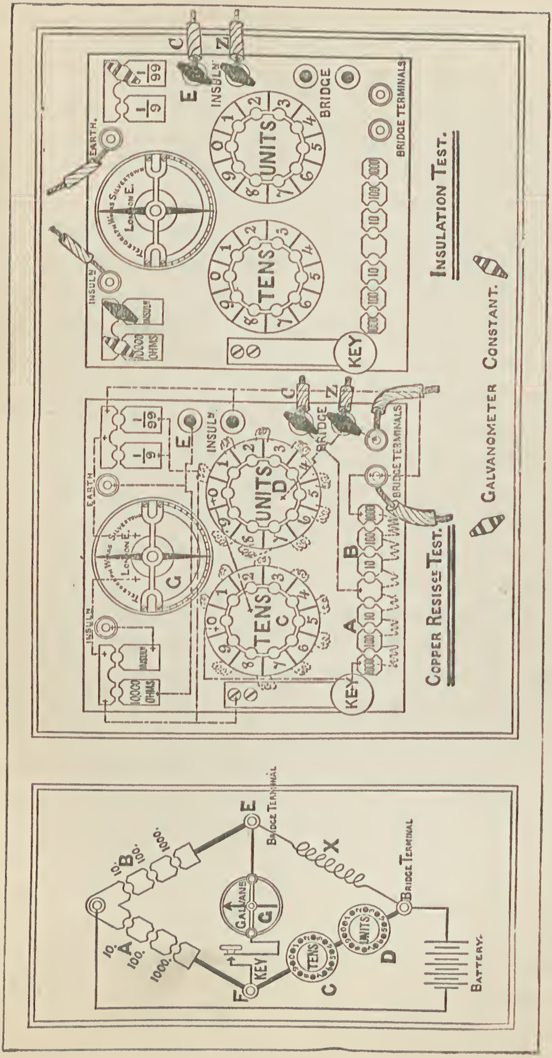

Fig. 24.

Fig. 25.

Fig. 26.

Diagrams of Conductor and Insulation Resistance Tests.

The resistance of a conductor is obtained by balancing known resistances against the resistance to be measured in the following manner :—

The resistances marked A and B are the ratio resistances, and in each test it is necessary that one should be unplugged in A and one in B.

The theory of the arrangement is the obtaining of equilibrium by the adjustment of the resistances in A, B, and C, D, until there is no difference of potential between the points E and F, and consequently no deflection of the galvanometer needle when the key is closed. These conditions can only be obtained when the resistances in the two sides X B and C D A are equal, or bear certain proportions to each other. Let us take the case of obtaining equilibriums with equal resistances. Make the resistance of the ratio sides A and B equal by unplugging the 10, 100, or 1,000 coil in each ; it will be obvious that a balance or state of equilibrium between the points E and F will be obtained when C, D=X ; it is therefore necessary to vary C, D until no deflection of the galvanometer needle is produced on repeated tapping of the galvanometer key, when C, D=X. It will be observed that by using equal ratio resistances, any resistance between 1 and 99 ohms can be measured, but by a suitable arrangement of the ratio resistances the range can be extended to from ·01 ohm to 9·900 ohms, for if the 10 coil in the ratio arm B, and the 100 coil in the ratio arm A are unplugged, a balance will be obtained when the resistance in C, D is ten times that of X ; therefore, C, D divided by 10 will give the resistance of X. In the same manner we may have the 10 coil in B unplugged and the 1,000 coil in A, in which case we divide the resistance in

C, D (when a balance is obtained) by 100 to obtain the resistance of X. High resistances are measured in the same manner, but the resistance in ratio arm B is made higher than that in A. For example, if we make B 100 and A 10 we multiply C, D by 10 to obtain X, and if B is 1,000 and A 10 we multiply C, D by 100. In the testing box the ratios are placed in front of the ebonite base; the left hand 1,000, 100, and 10 coils representing A, and the right hand 10, 100, 1,000 coils representing B.

The following table gives the most suitable ratios for measuring resistances between the limits stated:—

Between Ohms.	Ohms.	Ratio Right hand.	Left hand.	
900 and	9,900	1000	10	Multiply C, D by 100.
90 ,,	900	100	10	,, C, D by 10.
9 ,,	90	10	10	C, D = X.
·9 ,,	9	10	100	Divide C, D by 10.
·01 ,,	·9	10	1000	,, C, D by 100.

It will be found while adjusting the dial resistances C, D, that if the resistances to which the dials are adjusted is higher than X, the galvanometer needle will be deflected to one side, while if the dial resistance is lower than X, the deflection will be to the opposite side, becoming less and less as the balance is approached. When the balance is nearly obtained, the key should be pressed down repeatedly, in order to induce the galvanometer needle to swing.

To take an Insulation Resistance Test.—To obtain a constant, place the battery-wire plugs in the plug holes marked insulation, and plug up the 10,000 and $^1/_9$ or $^1/_{99}$ shunt in order to obtain a suitable deflection of the galvanometer needle; call this deflection θ, and the shunt used S.

Insulation :—Connect the terminal marked "earth"

to any convenient ground contact, such as a gas or water pipe, and that marked insulation to the conductor or circuit to be tested. Plug up the "insulation" switch (removing the plug from 10,000) and, if required, $^1/_9$ or $^1/_{99}$ shunt, reproducing as nearly as possible the constant deflection θ. Call the deflection of the galvanometer pointer D, and shunt S, then—

Insulation resistance in ohms=

$$\frac{\theta \times S \times 10{,}000}{D \times S} \qquad (1)$$

or, if no shunt has been used in the insulation test—

$$\text{Resistance in ohms} = \frac{\theta \times S \times 10{,}000}{D} \qquad (2)$$

Note.—The multiplying power of the $^1/_9$ shunt is 10, and that of the $^1/_{99}$ shunt 100.

Example.—Suppose the deflection θ, when taking the constant to be 45°, and the shunt being $^1/_{99}$, and the deflection D 20° with $^1/_9$ shunt, then, according to equation 1—

$$\frac{45 \times 100 \times 10{,}000}{20 \times 10} = 225{,}000 \text{ ohms.}$$

Example.—The constant deflection being as above, let the deflection D = 5°, no shunt being used—

$$\frac{45 \times 100 \times 10{,}000}{5} = 9{,}000{,}000 \text{ ohms or 9 meg-ohms.}$$

Portable Wheatstone's Bridge.—A very convenient portable bridge, for the comparing of small resistances (up to 100 ohms) has lately been introduced by Messrs. Woodhouse & Rawson. It measures only $5\frac{1}{2}$ in. in diameter, with a height of $3\frac{3}{8}$ in. The ratio wire is of platinum silver, arranged in a circular spiral form and stretched upon the thread of a double threaded screw, cut on an ebonite cylinder, and the connecting wire to one terminal of the battery

stretched on the other thread. Connection is made between the two by a spring and roller contact fixed to the inside of the ring-nut working on the screwed cylinder. The position of this nut, with its contact piece, determines the relative lengths of the platinum silver wire on either side. Four plug blocks are placed on the top of the cylinder, allowing a resistance of either ·01, .1, 1, or 10 ohms to be inserted in one arm of the bridge. Here are also the necessary terminals for connection to battery, galvanometer and resistance to be measured with a contact key. The arrangement is represented in Fig. 27.

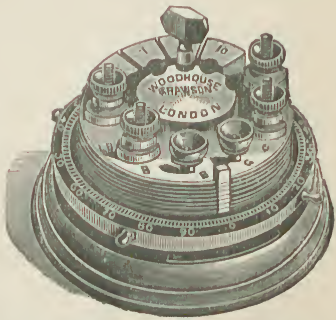

Fig. 27.—Portable Wheatstone's Bridge.

Insulation and Conductivity Tests during Wiring.—The simplest test, and indeed that to which the common wireman confines himself, is a test for continuity. The only instruments required for this consist of a battery cell of any portable kind, and a galvanometer of the simplest description. A wireman's "testing set" usually consists of a semi-dry Leclanché cell, a detector galvanometer, having a few hundred ohms resistance, and a connecting key, with suitable terminals. The whole is usually fitted into a small portable wooden case. But the only information such an equipment gives is warning of any break of continuity in the wiring.

There may be a serious defect in even the continuity, which the first attempt to pass a large current

would make manifest, and yet the continuity test might be satisfactory. Such a fault commonly consists of any one of the following:—

A wire practically broken, but yet partially connected by a portion of the wire only.

A wire broken right across, but touching at the break.

A twisted joint, without being soldered, but yet loose, *e.g.*, not rigid.

A loose safety plug or cut out, and yet in contact sufficient to give a deflection upon the galvanometer.

Wires are sometimes accidentally caught by the wireman's cutting plyers and cut *nearly* across without his knowledge. Such a point would heat very considerably when carrying full currents, and would finally be burned, opening the way for the formation of a dangerous arc between the severed ends. An arc of this kind would probably produce a fire.

To take the ordinary conductivity test it is only necessary to connect the battery cell, galvanometer, and wire, to be tested in series, and to complete the circuit by connecting the remaining terminal of the battery to the "return" end of the wire. The wire may, of course, be connected at its far end to the "general return lead," and in the case of ship wiring to the iron body of the vessel, but the connection through the wire will be the same as if the wire itself were continued back to the test box. If there is continuity a deflection of the galvanometer will ensue upon depressing the key. If there is a break there will be no deflection. If there be a very weak deflection, it may be due to ineffective connections at the box itself, or to some one of the defects already indicated.

Resistance Tests.—These are taken by several methods, and it may be said that each electrician has his own particular favourite plan. The two leading methods in practical use, however, are that given at p. 78 and known as the balance test (by Wheatstone's bridge), and that described at p. 75 known as the comparison of fall of potential method. The Wheatstone's bridge test is the most usually applicable, save to very small resistances, and will be found all that is necessary in everyday working.

The resistance tests are usually deferred until all the wiring is complete. Each circuit can then be taken in turn. In the case of an "installation" of the electric light, as in a house or ship, the tests should be taken from the main switch-board, close to the dynamo. In the case of house wiring for central station current the tests will begin at the distributing board where the leads join the connections (from the main) leading into the street. Circuits that are previously planned will probably be also estimated for resistance, and it should thus be very nearly known the resistance in ohms presented by each circuit. Such preliminary information facilitates and ensures the correctness of the tests, because the tests themselves should approximate closely to the calculated resistances. If they should vary the cause must be sought out. The tests themselves will be found fully discussed at p. 78.

It scarcely seems necessary to remind the reader that the extremities of the "branch" and "twig" leads must be temporarily connected together during the copper resistance tests; otherwise the movement would be through the carbon filaments of the lamps if

these happened to be connected. But lamp connections must be kept open during the tests.

Insulation Resistance Tests.—This test is becoming of greater importance in the case of house and ship wiring than the conductivity test itself. It is the test to which the fire offices will look for safety, and its fulfilment should be insisted upon by every fitter of the electric light.

The insulation test is of particular importance aboard ship and in all buildings where damp is likely to injure the insulation. The apparatus employed should consist of such a testing bridge as that described at p. 78 with its battery of 30 cells, or as many more cells as can be conveniently used. A small battery power is useless. The test itself is most easily taken according to the method given at p. 81. It should show an insulation resistance of at least ·1 meg-ohm * per lamp for every volt to be used on the circuit.

The earth connection made in taking the test should be particularly good. A water-pipe is usually a good earth—better than a gas-pipe, where joints interfere with the conductivity to earth.

The insulation aboard-ship, in cases where "ship return" is used, should be greater than that given above. In this case the "earth" will be the shell of the ship.

But an insulation test may show full value before the working current is passed, and may fall off under the E.M.F. of the dynamo. For this reason the test should be in duplicate before the current is turned on to the lamps, and after the lamps have been run for many hours. Aboard-ship, and in damp situations, the test should be repeated at intervals.

* Meg-ohm = one million ohms.

Insulation tests of overhead wires will show high in dry weather and low in damp weather. In the case of naked mains, underground, the same will hold good. Insulation tests of dynamo and transformer coils should be at least as high as that cited.

Details relating to installation and house wiring testing are more fully treated in Chap. V , p. 182.

CHAPTER IV.

ARC LIGHT WIRING AND FITTING.

A GREAT deal of the trouble that has hitherto been encountered in the general utilisation of arc lamps has arisen from ignorance on the part of those fitting up the circuits for, or attending to, the arc lamps. Now that the lamps and currents are becoming better known, more skilled attention is given to them, and a great impetus has thereby been imparted to arc lighting. It may also be pointed out that the revival of arc lighting (which, until lately, appeared likely to be eclipsed by incandescent lighting) is due in a considerable degree to improvements in the lamps themselves, to more effective insulators, superior methods of automatic regulation at the dynamos, and to a better quality of carbons.

The wonderful cheapness of the arc light, compared to the incandescent light, would prove a strong inducement to many to adopt it in place of gas, were it practicable to obtain in ordinary commerce plant that could be depended upon to yield a *reliable* and *steady* light. The general opinion of the arc light was, until very lately, that it had not yet passed the experimental stage, and that it was in consequence erratic and unreliable.

It should now be the aim of everyone interested in the new light to remove that impression, and to assist

in spreading a general conviction that arc lighting can be depended upon; that it is inexpensive and safe.

This can only be effected by first understanding the nature of the arc-lighting current, the nature of the dynamo producing it, the best means of controlling it, the most effective method of distributing the light, and the working and care of the arc lamp itself. In one item alone (carbons) the cost of the running of the light has recently been very greatly reduced. And by such improvements as the substitution of a laminated for a solid armature in a dynamo the cost of the light has been reduced by one-third.

The Obsolete Single-Arc System.—When arc lamps run from dynamos were first brought into use only one lamp could be put into the circuit of one machine. This was justly considered a great bar to the diffusion of the light, and altogether a costly system, necessitating as it did powerful lamps, only suited to special restricted areas. When Jablochkoff introduced his electric candle it was thought that arc lamps were entirely superseded, since several candles could be burned in the circuit of one dynamo. But an improvement was soon effected in the arc lamp, which opened up a means of putting any number into the circuit of one machine. We may glance at the early form and the improved form.

Single-Regulating Coil Arc.—All the earlier lamps were regulated by means of a coarse wire solinoid, through which the whole of the current passed. If the arc in this lamp became too long the solinoid, through the weakening of the current, would allow the carbon rod to drop, producing a sudden "wink" and re-establishing the proper length of the arc. This sudden disturbance *on the main and only circuit* would

be communicated to any other lamp on that wire, and would upset its arc. Every movement of the solinoid core, or every defect in the arc, would thus necessarily be imparted to the whole circuit. It was therefore impracticable to run more than one such lamp on one circuit. If two or more were put in a constantly flickering light ensued; some lamp would always be adjusting its arc and disturbing the others. This fault was overcome by a marked improvement, called a—

Differential or Shunt-regulating Coil.—The coarse wire coil was retained as before, with its iron core, supporting the upper carbon; but wedded thereto was a fine wire coil connected as a shunt to the arc. That is, when the current reached the positive terminal it had two paths open to it—through the coarse coil and the arc, and through the shunt coil direct back to the machine or negative terminal. If the arc became too long the current *through it* would tend to weaken, but this would cause a correspondingly stronger current to flow through the shunt, so that the current in the wires outside this lamp was not weakened. If the arc became too short the current *through it* would become stronger, but this would cause a correspondingly weaker current to pass through the shunt coil, so that the current on the outside wires was not strengthened. The shunt coil also exerts a control over the separation of the carbons, and by means of these *constantly balancing* factors, the current passing through the lamp is practically constant, and does not affect any other lamp.

These elementary explanations are offered in order to clearly distinguish in the reader's mind the nature of the lamps, with their balancing devices, suitable for single and multiple lighting. The construction of the

lamps themselves, in which many ingenious modifications have been introduced, can be studied in a good descriptive book on electric lighting.* The modifications are chiefly in the direction of making the lamps suitable for either *constant current or constant potential.* There is, at least, one lamp (the Brockie-Pell) which is so ingeniously adjusted as to fit it for working upon either circuit—that is, it may be taken from a constant current circuit and placed in a circuit where the potential is kept constant instead of the current, and it will burn very well. There is also a successful automatic cut-out in each lamp, so that if the carbons happen to burn out, the circuit will not be interrupted, but will remain open through the cut-out, leaving the lamp in a by-pass.

Arc lamps in parallel, that is, placed across the main leads, like incandescent lamps, work very well when fitted with resistances or "choking coils," as they are called.†

Arc lamps are frequently run upon *alternating current circuits*, when adopted for that purpose, and in this way are now run off transformers along with incandescent lamps—in this case, the arc lamp is, of course, placed in parallel across the leads.

Focussing arc lamps are those in which both carbons move towards the arc, are burned equally, and keep the arc in one place.

The distance between the carbons in arc lamps does not vary much. It always depends upon, and is nearly proportional to, the E.M.F. in the circuit.

With an E.M.F. of 50 volts and a current of 15 ampères the usual working distance is $\frac{3}{16}$ths of an inch. With a 40 volts E.M.F. and a 10 ampère

* See pp. 206—250 of "Electric Light," 4th ed. London, 1890.

† "Choking and Impedance Coils, p. 115.

current, $\frac{1}{8}$th of an inch is usually the most effective working distance. These figures apply to the ordinary powerful arc lamps used for street lighting when worked *in series;* when worked in parallel, the E.M.F. must be higher—usually about 20 per cent.

When a dynamo is running only one lamp its E.M.F. need not exceed 50 volts.

When a dynamo is running several lamps its E.M.F. must be proportional to the number of lamps. If each lamp calls for 50 volts, and there are 20 lamps *in series*, the E.M.F. developed by the machine must be at least 1,000 volts, with an allowance for fall of potential due to the leads and branches.

When a dynamo is running lamps in parallel its E.M.F. need only be high enough to run one lamp, with the usual allowance for resistance of leads. But its *out-put of current* must then be in proportion to the number of lamps; if one lamp takes a current of 10 ampères, and there are 20 lamps, the current must be at least 200 ampères.

The Series method of running is more economical.

Arc lamps are in use—*e.g.*, Siemens' differential; the Brokie-Pell—capable of giving a steady light with a current of only $4\frac{1}{2}$ ampères, in series. These are chiefly employed for indoor lighting. The minimum E.M.F. to secure a clear arc is probably 30 volts—*e.g.*, the carbons will not separate, and produce the true arc with less.

Regulation when running Arc Lamps in Series.—An ampèremeter is always placed upon the circuit near to the dynamo, so that the attendant can see at a glance the current flowing. He is chiefly concerned in keeping the current constant. This is frequently done by switching in more or less resistance; into

the main circuit, if the dynamo be a series-wound one, and into the field magnet circuit if it be a shunt-wound machine; but the shunt or compound wound machines are supposed to regulate themselves, which they very often fail to do. Changing the speed of the engine is more generally applicable to the regulation of constant potential circuits. There are several automatic constant current regulators, in use more or less efficient.

Regulation when running Arc Lamps in Parallel.—A voltmeter showing the volts is in constant use across the leads, and under the eye of the attendant. His chief care is to keep the *potential difference* between the leads the same. This is usually effected in part by the dynamo itself, when a shunt-wound machine is used, or by regulating the *speed*, which has in most cases a direct control over the E.M.F.

Arc Lamp Trimming.

Unsteadiness of the light is usually caused by small defects that are allowed to develop through the attendant not understanding his lamps. To work a lamp to the best advantage, especially if it be out of doors, exposed to wind and rain, calls for some little skill and familiarity with the mechanism of the lamp.

When lamps burn unsatisfactorily, and the cause cannot be found in the regulating mechanism, it may be due to the carbons used being faulty, or to poor insulation of the leading wires, but more frequently to the current or pressure (E.M.F.) not being suitable to that particular lamp. To obviate this the maker of the lamp should always issue with it the necessary particulars of pressure and current at which it is intended to burn. But most arc lamps contain within

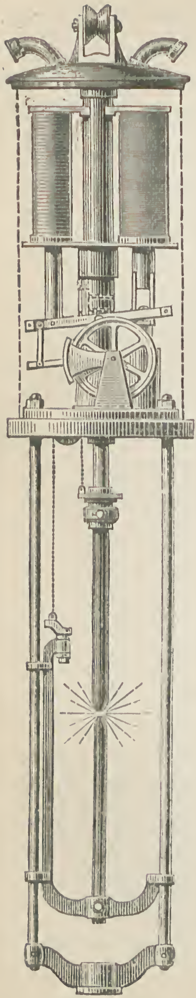

Fig. 28.
Brockie-Pell Lamp.

themselves mechanical balances, or other devices to enable the user to regulate them for himself, and to suit the pressure and current given by his dynamo. The carbons used must always correspond with the current, *e.g.*, thick carbons for a large current and thin ones for a small current. The length of the arc is always regulated to suit the pressure.

Fig. 28 represents the working arrangements of the Brockie-Pell lamp, and Fig. 29 its external appearance, encased ready for work.*

As an example of the attention that must be given to arc lamps to run them successfully, we append a few working directions applicable to the Brockie-Pell Arc Lamp .—

1. This lamp is regulated for a normal current of — ampères.

2. The current used must not exceed —.

3. The current must not be less than —.

4. To work at the maximum current (— ampères) take off the lead weight on top of piston of dash-pot.

5. To work with the minimum current (— ampères) fill the hollow piston with small shot.

6. In fact, to work with small

* For details see p. 218, "Electric Light," 4th ed.

currents, *add* weight to piston; to work with large currents *subtract* weight.

7. The piston is easily removed by simply unscrewing the dash-pot from the base-plate of the lamp; the plug at the top of piston unscrews, and the shot can then be added or taken out. Take care not to bend the piston link in unscrewing the plug, which may have become set fast. Put *no oil* on the working pivots or any other part of the lamp. *On no account put liquid in the dash-pot;* this should be absolutely dry, and will keep in good working order for many months; when it becomes too stiff simply wipe it out; use no emery or other cleaning powder in this or any other part of the lamp.

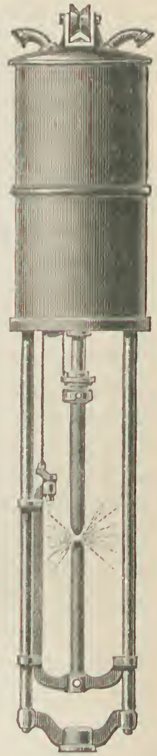

Fig. 29.
Brockie-Pell Lamp (encased).

8. Before inserting new carbons always wipe the rack, or sliding-rod and guide-rods, with a piece of soft leather; attention to this simple rule will keep the lamp in good order, whilst neglect will probably soon cause the rack to stick.

9. After the lamp is hung up, or fixed in position, see that the guide-rods have not become twisted; if they have set them perpendicular with the centre-rack.

10. To get the carbons exactly *in line*, and their points central with each other, insert the top *cored* carbon first, clamp it in the holder, and then observe if the point of the carbon naturally points to the centre

of the lower carbon holder; if not, unclamp the carbon, turn it round a little, and try again and again until it points fairly toward the centre, then insert the lower *solid* carbon, and adjust its point to the upper.

11. To secure a good light the distance between the carbons when burning should not exceed $\frac{3}{16}$ths of an inch, and $\frac{1}{8}$th of an inch is quite enough for a 10-ampère current.

12. The wires from the machines must be connected to the terminals of the lamp that the upper, or positive, carbon burns hollow and much brighter than the negative, or lower, carbon, which, on the other hand, burns to a slight point.

13. The rule is to connect the positive wire of the machine to the uninsulated terminal of the lamp. Should the carbons burn so that the light is thrown upwards, the wires must be reversed at the machine. If the lamp goes out and relights itself frequently, or a pumping action of the regulator takes place, it is a sure sign of the current being too weak, or of the machine magnetism being unstable—the lamp will *never* have this pumping action unless the current is at fault.

14. Should the lamp short-circuit itself by means of its automatic cut-out, the hand-switch must be used for relighting the lamp, unless it relights automatically.

15. The electromotive force necessary for each lamp when in series is about 45 volts; if the lamps are worked in parallel the electromotive force must be at least 55 volts, and a resistance must be placed in each lamp circuit to reduce the current in the lamp to what is required.

16. For parallel working on a — volt circuit this

lamp requires — ohms resistance in series with the lamp.

Adjustment of Brush System Lamp.—The treatment of arc lamps in which glycerine is used, in either dash-pot or carbon-holder rods, or in both, is rather different from the foregoing. The "dash-pot" in an arc lamp is simply a small cylinder, fitted with a piston and piston rod, the function of which is to prevent jerky or sudden descent of the carbon rod. In many lamps merely the piston, acting upon the air within the cylinder, is employed. In others glycerine, or a mixture of glycerine and water, is used to modify the movements. In the Brush lamp the dash-pot has to be unhooked from the armature and unpinned at the top, and then half filled with a mixture of three parts of glycerine and one of water. There is an air-hole in the top which must be kept clear. In replacing the dash-pot it must be so adjusted in its position that when raised to its highest point it is quite free from binding. The pin which secures the upper end of the piston rod must pass easily into its place, and must not bind in the hole in the rod itself. The piston rod must pass quite freely through the cover of the cylinder.

The brass carbon rods are tubes which carry the upper carbons (in twin-carbon lamps) and are the most important parts of the lamps as regards cleanliness, the perfect working of the lamp depending upon the regularity with which they feed the carbons. They may work irregularly through any foreign matter being attached to them—oxidation, or gummed oil. The fault may be in the bushes through which they pass, or in the tilting washers or rings which raise them, or in the pistons within them which

govern their fall, and prevent it from being too rapid.

In cleaning carbon-holder rods in arc lamps any polishing powder, as bath brick or emery, must never be used. This rule will be found to apply to all these lamps, embracing most of the successful ones, in which the feeding is done on the upper carbon rod, or in which that rod depends for its centricity upon its fitting its bushes perfectly.

The brass rods are merely wiped until bright with a piece of wash-leather and afterward polished dry. *Oil is seldom or never used to lubricate the rods*, and most arc lamps will be thrown out of action if oiled at all. It will be found to clog the action and to impede the flow of the current to the rods, and it will get carbonised by the heat and dried up by the heated air. If oil be used a good deal of trouble is in store for the attendant upon arc lamps. These remarks apply more particularly to the brass carbon rods, although they are generally true of the other working parts. The interior of the carbon rods in Brush's lamp is usually cleaned by a kind of ram-rod, using upon its end a plug of tow or cotton. If the interior has become gummy through the glycerine thickening, boiling water may be used to clear out the tube. In cleaning the brass carbon rods of lamps it is necessary to handle them so that there is no risk of bending or scratching. In the carbon rods to which these instructions apply a mixture of glycerine and water, as in the dash-pot, is used, the rod being filled when the piston is at the bottom. If the carbon rod on the positive side is correctly adjusted, it will gradually descend from top to bottom in the space of three minutes. The other rod takes a little longer. If the

rods descend too slowly the viscosity of the glycerine is too great and more water must be used. If too fast more glycerine must be added. The rods in this and every other arc lamp must work quite smoothly and have no tendency to "stick." In frosty weather it may be advisable, to prevent freezing, to add a little pure alcohol to the glycerine mixture. As received from the makers the carbon rods are usually filled with glycerine and ready for working, save that the plug screwed into the top, to prevent escape of the glycerine, has to be removed in order to allow of the plunger-rod being raised, so that it may be hooked on to its support in the chimney cap. The cap of the reservoir is not removed save when it is required to clean the latter.

Fresh carbons are usually 12 in. in length. The upper rod is to be passed into its socket as far up as possible, and the lower carbon adjusted centrally to it, so that there is a space of at least $\frac{1}{4}$ in. between the two carbons. If the carbons are of equal diameters, as they usually are, the bottom one will have a length of 6 in. only—the top carbon burns away twice as fast as the bottom. The proportions in length must be carefully observed, for if top carbons are too short in proportion to bottom carbons, the top will be burned away too soon, and fusing of its holder will probably ensue. The carbons must always be centrally in line with each other.

Whenever it is necessary to put carbons in a lamp, or to adjust the lamp in any way, or to handle it for any purpose, the switch must first be used so as to turn the current off that lamp.

If the lamp fails to light up on turning on current, see that the carbons are touching each other—they

must touch until the current begins to raise the upper carbon, on the establishment of the arc. If the automatic cut-out comes into play without apparent cause, examine the lamp to see whether the carbons are used up, or there is any obstruction to the free movement of the carbon rod.

When the arc is too long, it will look particularly blue, and have a flaming, unsteady appearance, with dullness—this shows want of proper balance in the parts, and they should be so adjusted as to give greater weight to the upper carbon, so that the raising solinoid will not have so much influence upon it.

When the arc is too short it will generally emit a hissing noise, indicating too high a temperature of the arc, and the light will be dull, chiefly through obstruction of the downward rays from the upper carbon crater. This can be remedied by so balancing the carbon rod that the solinoid will exert an increased lifting effect upon it. This adjustment, for both long and short arc, is effected in the Brush lamp by a steel-adjusting spring, which can be set at any desired position.

Arc lamps working upon alternating-current circuits must have careful adjustment for periodicity or phase of the alternating-current dynamo.

Focussing arc lamps are generally fed with an upper carbon twice as thick as the lower. This is especially the case in such a lamp as the Brockie-Pell, when made focussing. The lower carbon in this case is raised by means of cord communicators by the descent of the upper carbon. Both carbons must thus be of the same length, the difference in thickness being due to the positive (upper) carbon burning away the faster.

The diameters of ordinary carbons for general lighting, with lamps taking about 10 ampères at 45 volts, are from $\frac{3}{8}$ths to $\frac{5}{8}$ths in. These are lamps producing short arcs. For longer arc lamps, taking from 5 to 8 ampères at an E.M.F. somewhat higher, smaller carbons are used.

Arc Lamps in Series, with Incandescent Lamps in Parallel.—This system is in use in a few places of business, and even in street lighting, but it has proved itself one of the most troublesome systems yet tried. It is almost impossible to prevent the fluctuation of the arc lamps from influencing the incandescent lamps. This implies short life to the latter. Moreover, very few arc lamps can be thus inserted in a circuit. Suppose the pressure to be 100 volts, only three, at most, arc lamps could be run in such a circuit. The supposed economy of the system has led electricians to devote a good deal of time and thought to the subject. There are other fundamental defects in the system which cannot be entered upon here.

The most successful method of wedding the arc with the incandescent lamp is no doubt the ordinary parallel system, with not more than two incandescent lamps in series parallel. Each arc lamp to be in parallel singly. It appears at first the more expensive, but that is a question that can only be answered by practical trial. The young electrician, in planning for the running of arc lamps in parallel with incandescent lamps, must not forget that while his glow-lamps may at most only need an ampère each, the arc lamps will require a minimum of 5 ampères each —all of which considerations must be arranged for in the leading wires.

Arc Lighting Circuits.

Running Leads.—The simplest case in which leads can be run is that in which a dynamo machine on the ground is to be connected to a lamp elevated on a pole. It is, indeed, only a few years since—about 1880—that this was the only way to produce an arc light; each lamp had its own dynamo and pair of leads. But, as we have observed, improvements in the lamps and machines have put it in the power of the electrician to run as many as fifty arc lamps in series upon a single machine, or as many as he can find current for in parallel across the leads.

As may be expected, the insertion of a number of lamps upon the wires of a single dynamo, either in series or parallel, opens up practical questions of some little difficulty, and a great deal of trouble was encountered by the earlier experimenters in this direction. But most of the problems have been solved in the only satisfactory way—that of practical working, and the multiple series and multiple arc systems are now both pronounced successes.

The leading wires or cables are usually of copper, although iron has been used in some cases for high-tension working. They are almost invariably insulated, either practically or in name only. A properly insulated lead or cable will first be of tinned copper, covered by a sheath of pure india-rubber; then covered by a wrapping of *india-rubber prepared tape*, and, finally, a wrapping of tar-flax. The insulation may be carried much further than this, but, in either case, the wires so treated may be called insulated wires. The covered wires are merely covered, not insulated. They are usually of bare copper, with

a wrapping of cotton tape, previously prepared by passing it through some insulating liquid compound.

It will be convenient to distinguish between the two by calling the india-rubber covered wire *insulated lead*, and the cotton-covered wire *covered lead* only.

Technically, a *wire lead* is a single wire conductor. A *cable lead* is a conductor formed of several stranded wires, known respectively as wires or cables.

Insulation resistance is a point of much importance. It is usually expressed in terms of the meg-ohm (1,000,000 ohms) per mile. In tables the meg-ohm is frequently represented by the Greek letter **Ω**. The insulation may vary from 150 meg-ohms for ordinary insulated cable to 5000 meg-ohms for heavily-insulated and vulcanised cable. For low tension work, to be lined on insulators, the covering insulation is usually neglected, or naked wire only is used. For work of low tension, not lined on insulators, but merely laid in wooden channels, &c., the insulation giving 150 meg-ohms is generally considered safe.

For high tension work, not lined on insulators, the vulcanised rubber-covered cables are usually employed, giving 5000 meg-ohms insulation resistance per mile.

Mechanical protection is imparted to cables by hemp wrapping, wire braiding, or lead covering.

For outdoor arc lighting work cables are used in preference to wires. A wire above No. 8 gauge is stiff and difficult to handle. A stranded cable of the same capacity is much more flexible.

The legal gauge is now the recognised standard of measurement of wires in this country. It is very similar to the old Birmingham wire gauge, but is more complete, and affords a wider range.

In selecting the size of a cable consideration must be given first to the tension that is going to be maintained in the circuit. The size of the cable will depend more upon this than upon any other consideration. Let us take two opposite and extreme cases:—(1) For a single lamp, run by a small dynamo, giving about 15 ampères at 50 volts, the usual size of cable employed in practical work is composed of seven No. 20 wires; when the distance between the machine and lamp does not exceed 500 yards, or a total length of circuit of 1000 yards. Such a cable has a resistance of 6·175 ohms per mile. But the same cable will feed several lamps, if the electrical pressure in circuit be raised in proportion to the number of lamps. (2) Forty lamps are fed by a Brush dynamo through a cable composed of seven No. 16 wires, over a total length of a mile. The volts that can be afforded as loss in the cable will always determine its size. It is a question of cost of power and cost of cable. Theoretically, the larger the cable the better.

The standards in the following table have been adopted by the India Rubber and Telegraph Works Company, whose cables are specially prepared to suit the various requirements of electric lighting work. The insulation consists of several classes, ranging within the insulation resistances per mile already mentioned. For all arc-lighting work in the neighbourhood of buildings, where the wire is apt to be handled, or to touch conductors, the cables should be insulated, whether run upon porcelain insulators or not.

Ground leakage is the most troublesome opposing factor in the work of running an insulated arc lead for high tension. It can only be obviated by good insulation, either upon the cable itself or in the form of

GENERAL TABLE OF REFERENCE FOR ELECTRIC ARC-LIGHT CABLES.

PARTICULARS OF CONDUCTORS.

No. of wires in Strand.	Legal standard gauge of each wire.	Diameter: Of each single wire. In.	Diameter: Of each single wire. m/m.	Diameter: Of the Strand. In.	Diameter: Of the Strand. m/m.	Equivalent to solid wires. Diameter. In.	Equivalent to solid wires. Diameter. m/m.	Equivalent to solid wires. Area. Sq. in.	Equivalent to solid wires. Area. Sq. m/m.	Weight of conductor. Per statute mile. lbs.	Weight of conductor. Per Kilometre. Kilogrs.	Resistance at 60° Fahr. Per statute mile. Ohms.	Resistance at 60° Fahr. Per Kilometre. Ohms.
7	20	·036	·914	·108	2·74	·096	2.43	·0072	4·65	147	42	6·175	3·835
7	19	·040	1·02	·120	3·04	·107	2·71	·0089	5·77	182	52	5·002	3·1079
7	18	·048	1·22	·144	3·66	·128	3·25	·0128	8·30	262	74	3·473	2·158
7	17	·056	1·42	·168	4·27	·149	3·78	·0174	11·28	356	100	2·552	1·585
7	16	·064	1·63	·192	4·88	·171	4·34	·0229	14·73	465	132	1·953	1·213
7	15	·072	1·83	·216	5·49	·192	4·87	·0289	18·66	589	166	1·543	·9589
7	14	·080	2·03	·240	6·10	·213	5·41	·0356	22·98	727	205	1·253	·7785
19	20	·036	·914	·180	4·57	·159	4·03	·0198	12·74	402	113	2·261	1·404
19	19	·040	1·02	·200	5·08	·176	4·47	·0243	15·72	496	140	1·831	1·137
19	18	·048	1·22	·240	6·10	·211	5·35	·0349	22·66	715	201	1·271	·7897
19	17	·056	1·42	·280	7·10	·247	6·27	·0479	30·91	973	274	1·079	·6704
19	16	·064	1·63	·320	8·12	·282	7·16	·0624	40·25	1,270	358	·7154	·4445
19	15	·072	1·83	·360	9·14	·317	8·05	·0789	50·96	1,608	453	·5652	·3512
19	14	·080	2·03	·400	10·1	·352	8·94	·0973	62·77	1,985	559	·4579	·2845
19	13	·092	2·34	·460	11·6	·404	10·7	·1282	83·20	2,625	740	·3462	·2151
19	12	·104	2·64	·520	13·2	·458	11·6	·1647	106·3	3,354	945	·2709	·1683
37	16	·064	1·63	·448	11·3	·394	10·0	·1219	78·6	2,482	699	·3661	·2274
37	15	·072	1·83	·504	12·8	·443	11·2	·1541	99·58	3,142	885	·2892	·1797
37	14	·080	2·03	·560	14·2	·493	12·5	·1909	122·9	3,879	1,093	·2343	·1456
37	13	·092	2·34	·644	16·3	·566	14·3	·2516	162·6	5,130	1,445	·1772	·1101
37	12	·104	2·64	·728	18·4	·640	16·2	·3217	207·7	6,555	1,847	·1386	·0861
61	13	·092	2·34	·828	21·0	·728	18·5	·4162	268·7	8,477	2,389	·1072	·0666
61	12	·104	2·64	·936	23·7	·823	20·9	·5319	343·4	10,832	3·052	·0839	·0521

porcelain cups. Next to ground leakage, the danger of *short-circuiting* is doubtless the most common. This latter is *dangerous* in two ways. Within a building *a short circuit may cause a fire*, by establishing an electric arc, or by heating a wire red hot near to woodwork. Outdoors it may burn up the armature of the dynamo and destroy the instruments. It may be remarked, in passing, that the use of special gear, flanges, &c., for the purpose of keeping a belt from slipping off a dynamo pulley is not advisable in all classes of work. *The slipping of the belt frequently saves the dynamo from destruction* when a heavy load is thrown upon it by accidental short-circuiting. A short circuit is got when the naked leads touch each other. It more generally happens through both leads getting into conductive contact with metallic substances, as girders or gas pipes. Ground leakage is generally due to wet or moisture conducting the current to earth. If the dynamo be well insulated, the tendency to ground leakage will not be so marked. The insulation of an outdoor line is generally good in dry or frosty weather, and is more likely to become faulty in wet and stormy weather.

Damages by lightning cause a great deal of trouble. During a thunderstorm outdoor leads generally give some indication of it in the dynamo room, and flashes will frequently be seen playing about the switch boards. This is usually obviated by a device called a lightning arrester or protector. It consists in many cases of two serrated plates (toothed plates are still more efficient) connected to the positive and negative leads, and so adjusted in a frame as to be face to face with a copper plate connected to a good earth plate, or other earth connection between them, very close

together, without touching. The tendency of lightning is to readily discharge itself from *points and ridges* across the shortest gap *to earth.* Fusion of armature coils is the usual result of a lightning discharge passing into the line and not finding "ground." Lightning arresters should be frequently examined, because they may be disabled by coming into use unknown to the attendant, or the serrated and earth plates may even be fused together.

The well-known fact that a magnet will repel an arc from between its poles is the principle of the improved lightning protector used by the Thomson-Houston Company. The apparatus is represented in Fig. 30, and consists of a powerful electro magnet, the field of which is occupied by two metallic horns. A lightning stroke passing over the line to machine is arrested at this point and diverted to earth.

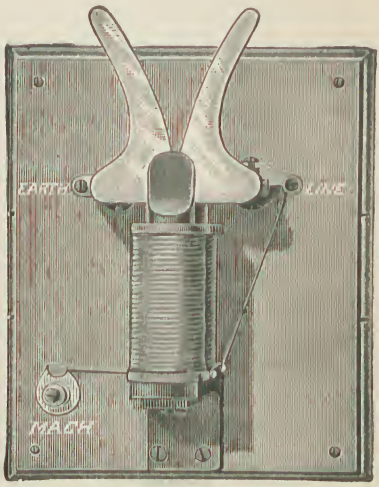

Fig. 30.—Lightning Arrester.

The use of lightning arresters is now considered essential in connection with all outdoor arc lighting lines.

Pole and Wall Insulators for the support of the leading wires are almost invariably of porcelain. For

out-of-door work, especially where good insulation is desirable, as when high-pressure currents are carried, Johnston & Phillips's fluid insulator, of the cup type, has proved itself one of the most efficient yet tried. The insulator contains (Fig. 31) a small annular cup-space, containing a little resin oil, which adds enormously to the insulating power of the support. The insulators are filled with a little syphon (Fig. 32). For very high tension work the insulator is made with two spaces for the insulating oil (Fig. 33).

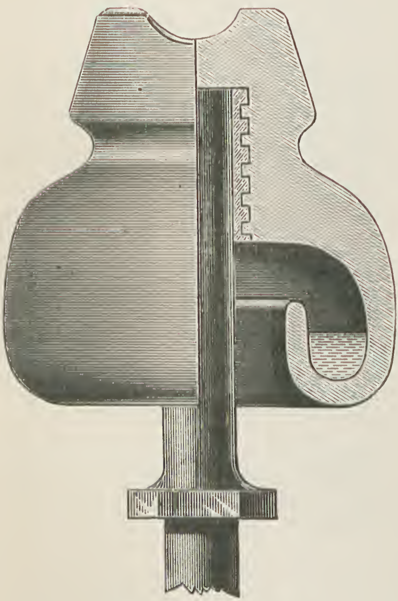

Fig. 31.—Fluid Insulator.

Heavy arc lighting leads are usually supported by independent insulators at each pole, the cable being severed, and, after being securely shackled off, reconnected electrically by a loop. In addition to these precautions, heavy leads—as main leads—are sometimes borne upon a steel rope.

This particular kind of work, known as "overhead line running," in which both earth and housetop poles are used, scarcely comes within the scope of our pages. We can only point out the more im-

portant precautions to be taken in running leads for house lighting, and perhaps indicate the nature of the insulators and other adjuncts employed.

Naked leads must in every case be carried upon insulators. They must not be hung so near to each other that by any accident they may come into contact. A space of nine inches is the usual minimum between them. The authorities of towns will not usually allow such leads to be carried across streets. In such case an insulating covering is always required.

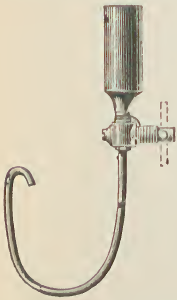

Fig. 32.—Syphon for filling Insulator.

Fig. 33.—Fluid Insulator. Double type.

Naked wires of any kind should never be carried indoors, or near to any inflammable substance.

Lightly insulated leads should be carried upon insulators. They are not quite safe when laid in wooden troughs, especially where there is any danger of the covering being abraded. If such a lead were to get a good chance of contact to earth a very little pressure or attrition would cause a short circuit.

Properly insulated leads should be carried upon insulators, if practicable, outdoors. Indoors such wires may be laid in wooden troughs, run under cleats along flooring, and so forth, but should be kept away from damp walls or iron piping. The distance

between them if carried in cleats should never be less than 3 inches. Most fire-offices insist upon a greater separation. The rules recommended by the Institute of Electrical Engineers, given at p. 212, should be referred to on this point.

Heavily-insulated leads may practically be laid anywhere, so long as they are protected from mechanical injury. They are frequently laid in wet trenches (some well-insulated cables are best laid in water)

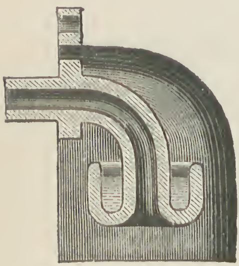

Fig. 34.

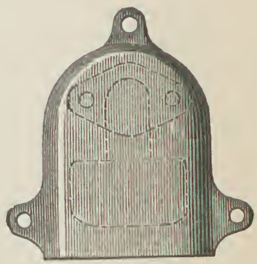

Fig. 35.

Wall Conduit Tube.

and may be carried upon damp walls. The mechanically protected leads, having a wrapping of heavy tape over all, or an armour of steel wires, or a casing of lead, are adapted for main lead work, where large currents are carried.

Danger due to Metallic Armour.—It may be pointed out that leading cables provided with metallic armour are frequently a source of danger, through the additional risk of connection between core and sheathing, as it will be discerned that such a contingency is quite equivalent to *uninsulating* the whole cable.

When a branch is taken off through a wall into a house the aperture must be made in the wall *above* the terminal insulator. A porcelain wall conduit-tube,

Figs. 34, 35, which represent the conduit in section and front elevation, and furnished with the fluid insulator, must be used in passing the lead through the wall. If there are two leads the pair must not pass through one tube, unless it be divided by an insulating partition. The wire is carried upwards to prevent rain and wet from following the surface into the wall.

The apertures in partitions and interior walls must in every case be lined with either porcelain tubing or vulcanised rubber.

In high-tension arc lighting within mills, stores, and so forth, the lead should always be exposed to view, and run upon insulators several—many offices insist upon 12—inches apart. If a wire must be concealed it must be heavily insulated at that point.

In low-tension working, as when the arc lamps are run in parallel with a pressure not exceeding 50 volts, the leads, if well insulated, may be run upon woodwork and fastened by wood cleats or leather loops.

The making of *joints* and *splices* will be found more particularly described in Chapter V., p. 190. Joints must be good *mechanically*, so that their breaking strain is greater than that of the wire.* They must be made good *electrically* by soldering. Every joint must be heavily insulated after it is complete by a wrapping of prepared tape.

Planning a System of Mains and Feeders.—An admirable system of preliminary planning in getting out a network of main leads, with the necessary feeders for keeping the potential equal at all points, comes from Berlin. The German Edison Company take a large frame or table, and make a clear plan

* The ordinary telegraphic mechanical tension-resisting joints are fully described at p. 302 of "Electric Light," 4th ed.

thereon of the streets, buildings, &c., to be covered by the system. The location of the central station is then marked, and two wires from a small battery run to it to represent the electric supply. From this point the main leads are all laid down in miniature, along the plan of the streets, and each group of lamps is represented by a wire resistance. Current is kept upon the system, and the drop of potential at each point carefully noted by galvanometer. Feeders are then run to equalise the potential, and by means of careful measurement every detail of the system can thus be ascertained. The model network is kept at hand, and as any alterations are required in the real net-work they are first made upon the model. This is of course much better than any possible paper-and-ink system of planning.

English engineers generally get out their plans upon paper, marking off the lengths of cable and location of lamps, and calculating the carrying capacity of the main leads upon the basis of 1000 ampères per square inch sectional area of leading wire. These systems have, however, more particular reference to incandescent lighting, and the reader is referred to Chapter V. for rules and tables from which can be ascertained the best size of conductors to employ for any particular installation, or number of lamps, at various distances, with various losses upon resistance.

Transformers or Converters.

The fundamental conception of the modern transformers is represented diagramatically in Fig. 36, where D is a dynamo, in whose circuit the primary coil P is placed. The electromotive force in this circuit is supposed to be high, say 1,000 volts. S

generally regarded as presenting no resistance to the current similar to that offered by a wire, but it is seldom or never used in electric lighting, on account of other considerations explained further on.

This fall or drop of potential or "pressure" is due, in the first place, to the resistance of the circuit. The greater this resistance the greater the fall of pressure. Again, with a given resistance of wires the pressure falls off in proportion as we increase the current. This is the varying pressure that must be met, as explained in Chapter I., p. 27, by increasing the pressure at the dynamo. A certain fall is due also to leakage.

In plain words, the resistance causes a loss of working power, and the switching on of more lamps also causes a fall of pressure. The loss due to resistance is great or small according as the wires are small or large, or long or short. A wire of a certain gauge, 100 feet long, will incur a loss of pressure just twice that due to a wire 50 feet long. A wire of a given *sectional area* will incur twice the loss due to a wire of *double the sectional area*. In circuits where the wires are of even thickness, and the lamps equally distributed, the fall of potential will be even. In others, where the sizes of the wires vary, or the lamps are unevenly distributed, the fall of potential will be greatest where the wire is thinnest and where there are most lamps.*

A certain loss in leading the current to the lamps is unavoidable. Practical men know fairly well how much loss they can afford. The thicker and shorter the

* To enable the reader to fully grasp this part of the subject, careful study of the laws of the circuit may be said to be essential. A simple enunciation of Ohm's law, bearing upon this question, is given under "Estimation of the Electrical Power," further on (p. 184).

wire the smaller the loss. Wires are selected to keep this loss down to *two and a half* per cent. of the total. A practical wiresman will say that he loses 5 volts from dynamo to lamps—that is, $2\frac{1}{2}$ volts in the main leading to the building and $2\frac{1}{2}$ volts in the lamp circuits. To run 100 volt lamps his dynamo must yield at least 105 volts. $1\frac{1}{4}$ per cent. of this will probably be due to the resistance of the "*leading*" wires, and $1\frac{1}{4}$ per cent. to that of the "*return*" wires.

The leading wire, or briefly "lead," is usually that representing the positive terminal of the dynamo, sometimes called the positive or feeding wire. The return wire is that leading to the negative terminal of the dynamo, called briefly the "return" or negative wire.

If the above 105 volts be absorbed in lighting the circuits of lamps, 100 volts will be lost in the lamps themselves.

The proportional fall of potential (the volts lost) is less and less as the pressure in the circuit is increased; but the highest safe pressure for use in houses is not above 200 volts, and lamps are not constructed for ordinary candle powers taking so much pressure as this. Thus, while a No. 16 wire can be made to safely and economically carry *six* lamps, requiring a pressure of 100 volts, the same wire would not be used for more than four lamps requiring 50 volts only. These facts will, however, be better understood by rules for calculations given further on.

The Series Multiple Method.—The great advantages of the parallel system we have just spoken of are that each lamp is independent, and that a safe pressure can be maintained on the wires. Thus the breakage of any lamp, or the switching of it off has no effect

upon adjacent lamps. But the economy in conductors and energy to be derived from the use of higher potentials has brought into use a system of *connecting more than one lamp* on a wire between the mains (Fig. 44). It is usual to connect two lamps in this way, and sometimes three or more. The diagram represents a pair of mains with a pressure of 200 volts, and shows that four 50-volt lamps may be arranged upon them in series, or two 100-volt lamps. The great disadvantage of this plan is the certainty that if one lamp should break or be switched off, the other must also cease to burn. It is true that

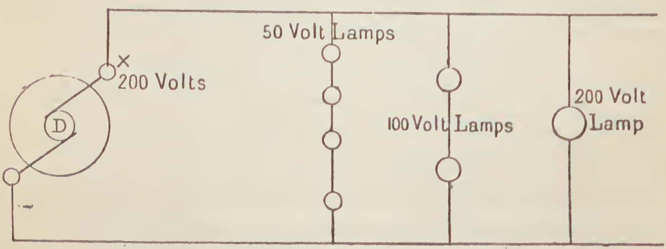

Fig. 44.—Diagram of Series Multiple Circuit.

this fault of the system has been combatted by an electro-magnetic switch, which keeps the circuit open, or provides a by-path for the current in the event of a stoppage of one of the lamps. But the use of such apparatus complicates the case very greatly, and introduces other troubles, the worst of which is the risk of fire. Besides these disadvantages, where this system is in use there is no saving of energy when half the lamps are switched off, because the magnetic switch has to insert a resistance into the circuit as great as that of the supposed broken lamp.

The multiple series system is used chiefly for large groups of lights, as in shops or theatres, where all the lights are required together. A useful and convenient combination of the parallel and series parallel may be made by bridging the main leads with two lamps in series as in the diagram. Thus, if the ordinary parallel lamps in the building are 100-volt lamps, the light at any point may be split into two separate portions by using two 50-volt lamps in series. As a matter of course, if one of the lamps should fail, the other upon that bridging wire will cease to burn. One switch serves for both lamps.

The Three-Wire System.—This is a system that has been brought into use more especially for main distribution work. It is chiefly employed for street mains. It may occasionally be utilised in large buildings. But for general wiring the three-wire system is not necessary.

Its main object is to effect a saving of copper conductor, and as this saving is very large the three wire system is coming into favour. The practical wiresman may have something to do with the system, if not in wiring a building, yet in making connections to it, and it may be well to briefly examine it. In the three-wire system the volts used are twice that employed on any parallel two-wire system, and the current (ampères) is only one half that used in common parallel.

In the working of the three-wire system two dynamos are used, connected to three conductors, as in Fig. 45. The dynamos are joined in series, and the central wire would therefore appear to be an idle wire. But when lamps are connected in the system they should bridge from negative wire to centre and from positive wire to centre, alternately, as repre-

sented. The inventor in this country (Dr. J. Hopkinson, F.R.S.), however, intends his three-wire plan to apply to *alternate houses* in a street. The central wire may be of much smaller section than either of the other two, as it has only to carry the *difference* of current between the two divisions of consumers,

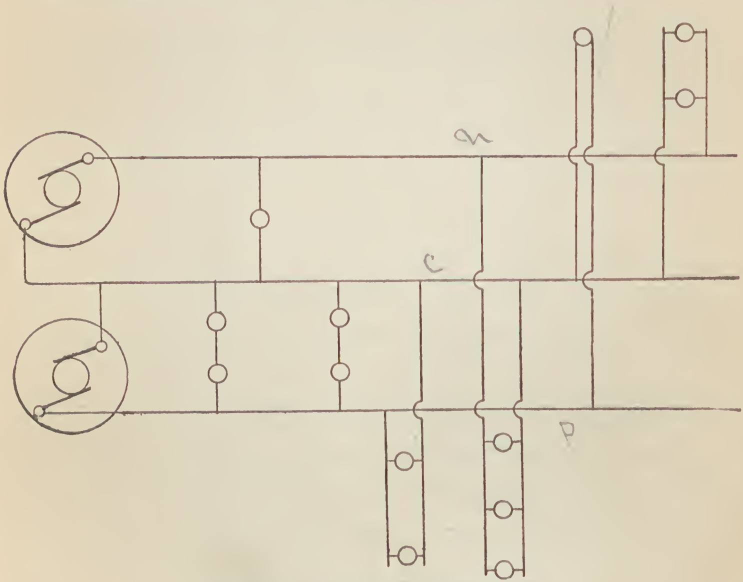

Fig. 45.—Diagram of the Three-wire System.

and is frequently an earthed conductor—that is, uninsulated; but this latter plan is not resorted to unless the two divisions of consumers require an approximately equal supply.

While the three-wire mains carry a current at, say, 200 volts, only 100 volts enter the houses when connected as shown. Therein lies the advantage of the system in respect to ordinary house wiring.

Series System.—This system of wiring is seldom used. Indeed, it is quite impracticable when carried further than a few lamps. It will be observed from the diagram, Fig. 46, that the lamps are merely connected one after the other, the whole of the current passing through every lamp. A line of 50 lamps thus con-

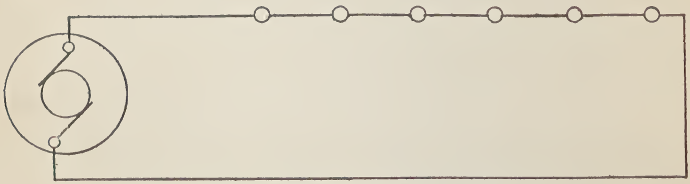

Fig. 46.—Diagram of the Series Method.

nected, if each lamp used 100 volts, would call for a pressure of 5000 volts. The system has merely been experimental, and it presents the very great disadvantage that a failure of any lamp breaks the circuit.

Multiple Series.—This is a more practicable development of the same idea as that just described. It is frequently employed when arc lamps are to be run

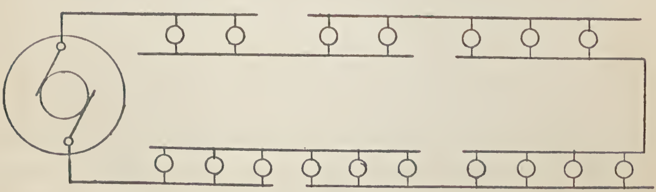

Fig. 47.—Diagram of the Multiple Series Method.

in connection with incandescent lamps. Fig. 47 represents the arrangement diagrammatically. It will be noticed that if one or two lamps should break in this system, the circuit would not be interrupted. The

other lamps in that group would become much brighter, consequent upon their having to pass on the same current as was before carried by a greater number. All the lamps in one group must be 100-volt or 50-volt lamps, as the case may be. If the lamps are all of equal voltage, the number in each group should be the same.

In this system the *current* must be kept constant, and a series-wound dynamo is generally used. The current will vary as the number of lamps, and the pressure as the number of groups upon the circuit. Hence, if the number of lamps varies, the current must be increased or diminished to correspond. If the number of groups varies, the pressure must be adjusted in proportion. In the diagram the circles represent incandescent lamps; but if it be required to burn an arc lamp, it can be effected by inserting it in place of one of the incandescent lamps. Thus the arc and incandescent lamps are run upon this system in parallel. The arc lamp will of course take a great deal more current than the incandescent lamp, and may replace several of these in a group, or even a whole group. Arc lamps to run on series parallel wires must be furnished with automatic cut-out or by-pass, so that the current is not interrupted on a failure of the arc. Only differentially (shunt) governed lamps should be used. The running of the system calls for considerable care on the part of designer and attendant, and an impedance coil is required.

Working Off Transformers.—The diagrams (Figs. 48 and 49) represent the usual arrangement of running parallel circuits off convertors, alternating currents being employed. The diagrams are self-explanatory.

Lamps in Parallel.—In Figs. 50 and 51 (p. 138), D represents the continuous current dynamo, M S, main switch and fuses, S, switches and branch fuses, L, lamps run in groups upon branches from the mains.

Other Systems.—Several others have been tried. Most of them have never merged from the experimental stage. Broadly speaking, there is one system used for the running of incandescent lamps—parallel

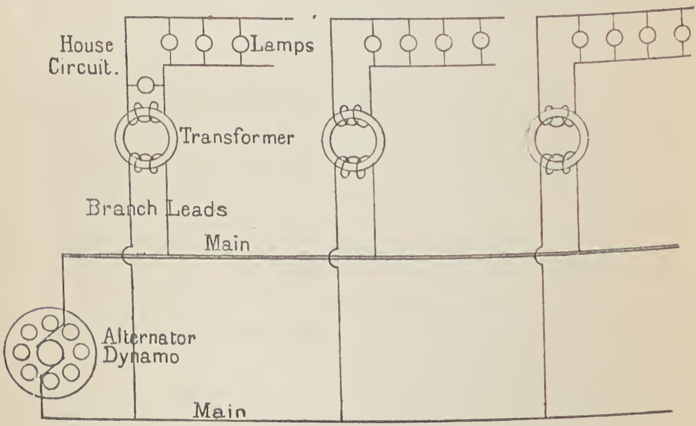

Fig. 48—Diagram of Transformers in Parallel.

or multiple arc—and although for special purposes one or other of the different systems spoken of in these pages are occasionally used, the parallel plan seems likely to hold its position as the first, simplest, and best.

Selection of a System.

Alternating v. *Continuous Currents.*—Considerable experience in this country of both systems does not appear to show that one system has any advantages over the other. There is a certain wastage of the carbon filament of lamps in both cases. The wastage

is impartial with the alternating currents—it appears to occur equally over the length of the filament. With the continuous current it is partial to the positive connection of the lamp, and this end of the filament waxes

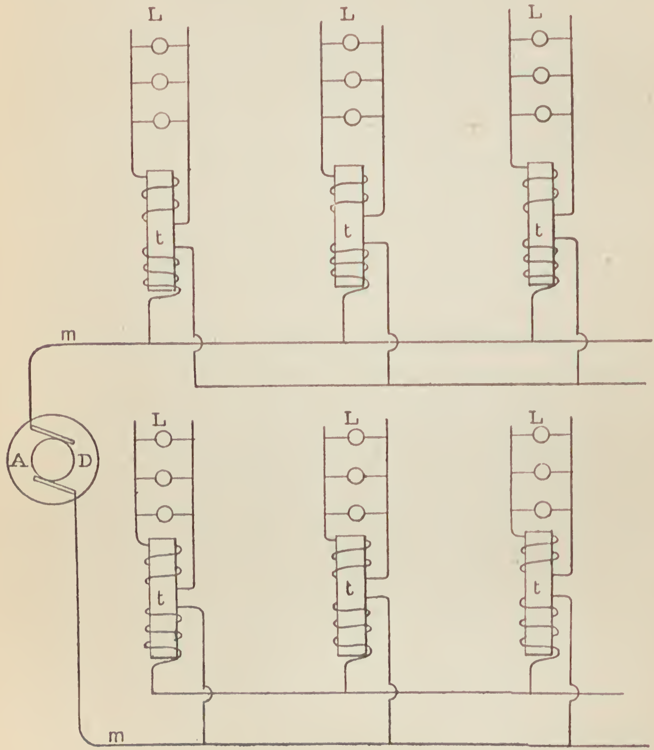

Fig. 49.—Diagram of Transformers in Parallel.

thinner than the other—the final rupture usually occurring at the end joined to the positive lead.

When lamps are run off street mains, and a *transformer* is used, the alternating currents are always

employed. When the street mains convey continuous

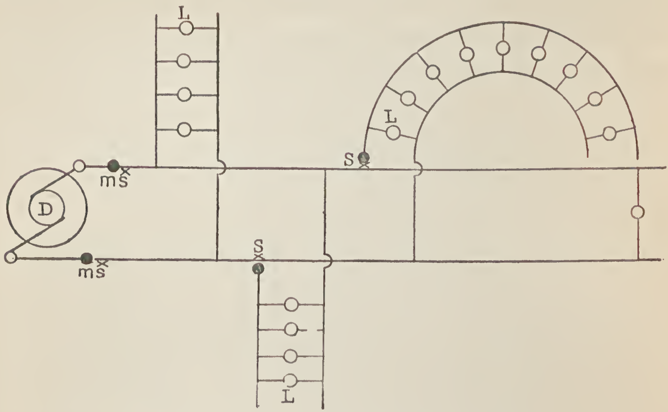

Fig. 50.—Diagram of the Parallel System of Wiring.

currents, the same currents are always used in the houses. When lamps are run off an accumulator

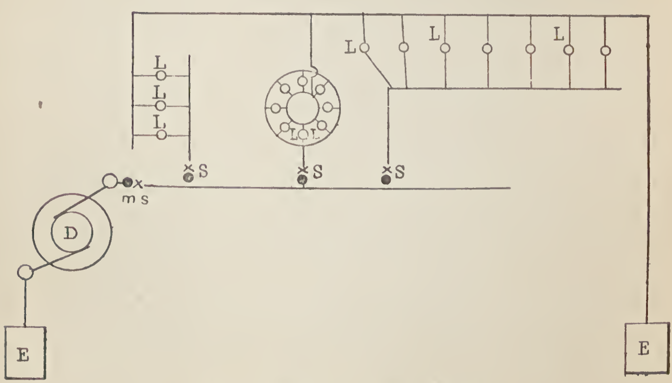

Fig. 51.—Diagram of Parallel Wiring.

continuous currents are employed. When they are run off a dynamo direct the currents may be either

continuous or alternating, according to the nature of the machine. The balance of opinion appears to favour alternating currents for incandescent lamps.

Parallel or Parallel-Series.—If the voltage of the street main be 100 it is the general custom to use the ordinary parallel system with one lamp across the main wires, as already explained. If the current entering the house have a potential of 200 volts, it is common to put two such 100-volt lamps across the wires, in series, as shown in the diagram given on p. 131. It is not advisable or usual to put more than two lamps in series in houses. If it be desired, 50-volt lamps can be run in pairs in series across wires at 100 volts.

When a Dynamo is Used.—In isolated plants it may be said that it is scarcely sufficient to rely entirely upon the dynamo. It is much more satisfactory to couple with it an accumulator. If 50-volt lamps be employed, 26 cells of accumulators will be required. The *number of lamps* such a battery will run will depend upon the *size* of the cells. Taking each lamp roughly at 1 ampère, it will depend upon the current in ampères evolved by the cell at an economical rate of discharge. The rate of discharge being estimated at about 4 ampères per positive plate of the large "L" type of E.P.S. cell (p. 46), the total discharge is equal to 50 ampère hours per positive plate, so that each positive plate would discharge about 4 ampères for 12 hours. There being 7 plates the total discharge will be from 25 to 30 ampères. Hence, from 25 to 30 lamps, taking approximately an ampère each, can be run from the battery we have supposed. In estimating the number of cells required

for lamps of odd voltages, divide the number of volts by 2, and add two cells as "reserve" (p. 51).*

The continuous-current dynamo must yield a current of sufficient strength to charge the accumulator. Further instructions will be found at p. 45.

An alternating current dynamo in an isolated plant will work direct on to the lamp circuits. There is this little advantage in the alternating dynamo, it is less liable to faults of conduction. Having no commutator or commutator brushes, breakdowns are much less frequent.

In making suggestions for selecting a system of working it is impossible to enumerate in a book all the possible variations from the fundamental rules already laid down. The reader must carefully consider his ground. In wiring houses for lighting from street mains the system and voltage are already there. He has only to lay his circuits, and choose his lamps to suit. In selecting an isolated plant, or a ship plant, he will be led by the requirements of each case; the balance of opinion is in favour of having an accumulator in reserve, especially in house lighting. Theatres are lighted both without and with accumulators. If they are not used, ample spare machinery should be provided in case of emergency, and in either case the circuits are frequently laid in duplicate, one set being kept in reserve; this latter precaution applies especially to the auditorium.

Planning of Circuits.

Broadly speaking, an installation of 100 lamps should be divided into at least two circuits. In many

* To understand the grouping of the accumulator cells a knowledge of the laws of the voltaic circuit is essential, for which see a good text-book. In simple cases the figures given by the makers of the cells are ample.

cases 50 lamps is too large a number to place upon a single pair of wires. The result will be more satisfactory, in respect of the electrical distribution, if three or more circuits are planned for.

Low voltage work—50 volts and under—is unusual in this country; 100-volt lamps are the rule. When the wire section is not restricted high voltage circuits will carry a greater number of lamps than circuits with only 50 volts.

The Distributing Box System.—According to this plan of arranging the wires all the switches (save in-

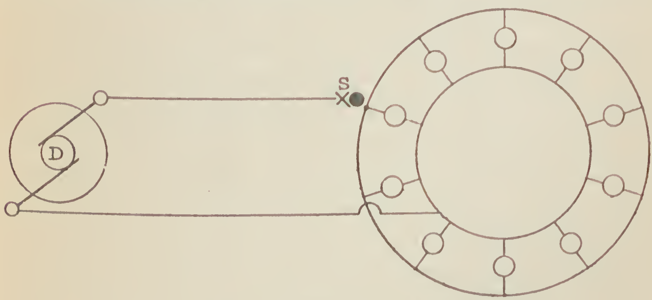

Fig. 52.—Diagram of Closed Loop, Parallel System.

dividual lamp switches) and safety fuses, or cut-outs, are placed upon a general switch-board, to which the mains from the dynamo are attached.

This switch-board is usually enclosed, under lock and key, and is called a "distributing box." From this point radiate all the circuits, with safety fuses at their roots, also double cut-out switches. The safety fuses should be fitted to both negative and positive wires. On the alternating current system there is no negative and no positive wire. Each wire becomes a — and a + pole many times in a second. American wiresmen call this box a "closet."

Before entering upon the uses of cut-outs, fuses, and so forth, it may be as well to point out that there is a certain advantage in some cases in locating all the accessories of the circuits at one point. It appears especially suitable to hotels and large institutions. On the other hand, it has its disadvantages.

Closed Loop Circuit.—Lamps are very frequently put in a closed loop circuit, as in Fig. 52. In this case it will be found most advantageous to connect as shown, or if the loop be large, to connect feeders from opposite sides.

The Tree System.—Professor Forbes * has given the name "tree system" to the plan represented in the diagram Fig. 53. Here we have the connections to the mains—street or dynamo—with "main fuses" and key switches—at the root of the tree. Thence lead a pair of sub-mains, forming its stem, throughout the main length and breadth of the building. From them spring "branches" or room circuits, and from these "twigs" or single lamps, representing the leaves.

Thus there are three sizes of wires usually employed. Coarse wire for the house mains, medium for the branches, and finer for the twigs, according to the current to be passed by these wires.

It will be observed that the safety fuses in this case (each fuse being represented by a *black* circle, and the lamps by light circles) are distributed throughout the system, one at least being placed at the root of each branch. Keys, or switches, represented by ×, are also placed at the roots of the branches, or as near thereto as may be convenient. It is usual to fix switches and fuses close together.

* See "Cantor Lectures," given before the Society of Arts, Feb. 1885, by Prof. George Forbes.

The three-wire system, already described (p. 132), is sometimes used in order to reduce the pressure from the mains to one-half, and to effect a saving of conductors. But it is only in particularly extensive installations that this would be done.

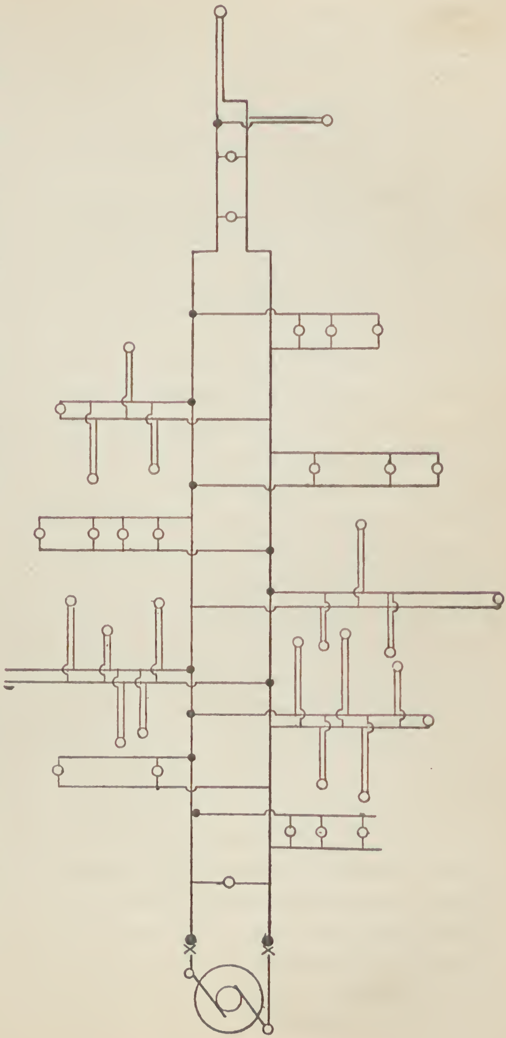

Fig. 53.—Diagram of the Tree System.

Size of Wire for the Circuits.

The Board of Trade rule allows a current of 2000 ampères per square inch of section of pure copper conductor of equal conductivity. This current will, however, be found

to make common copper wire rather hot. Practical electricians seldom allow more than half this current in the conductors — 1000 ampères per square inch. This current will not sensibly warm a wire of 95 per cent. conductivity, and is quite safe.

According to this latter rule it is only necessary to consult a reliable table, giving the standard sizes of wires, with their *section per square inch*, to ascertain the gauge required to carry a current of so many ampères.

It is a common practice in works on electric lighting to provide a mass of untested data from various sources. The beginner is expected to puzzle over these as best he can; but it will be found that, save in rare instances, such information is unfitted for the use of practical men. We do not propose to follow this rule, or at most will give only one or two examples of useful tried formulæ essential in practical work. Nor do we propose to weary the reader with cut-and-dried "examples" and "demonstrations" of the formulæ, for the simple reason that they are of no utility to a man about to plan an electric wiring system based upon conditions whch can never be foretold in a book.

The following table provides in a ready form a good deal of information. The first column gives the sizes of wires in use in this country, according to the legal standard gauge brought into force recently. This gauge is very similar, save in fine and coarse sizes, to the older Birmingham wire gauge. When a conductor is as thick as a lead pencil No. 6) it is too stout and stiff to be used for wiring. The practice is to substitute a *cable* composed of several smaller wires

stranded. Columns III., IV., V., and VI. are generally useful, while columns VII. to X. are of especial importance to the electrician. Column IX., giving the sectional area of the wire in square inches, enables a rapid calculation to be made as to the required size, on the generally used basis that 1000 ampères of current can be allowed per square inch area. Columns XII. and XIII. give the resistances in ohms per 1000 feet and per pound weight, figures which will be found a useful check upon the quality (conductivity) of the wire, and in testing.

Column XIV. is based upon the rule which allows 1000 ampères per square inch, and is approximately correct—for practical working quite safe. Many successful electricians work to such a column as this with perfect satisfaction.

Columns XV. and XVI. are approximate only, and give the number of lamps of different voltage that are usually successfully run from the wires.

The figures given in the table are intended to apply more especially to house wiring, where the distance between the dynamo or mains and the furthest lamp does not exceed 100 yards. It is taken for granted that not more than 50 lamps are placed upon one circuit.

In taking resistances of circuits it must be borne in mind that the resistance of a parallel system of electric lamps and leading wires is a combined resistance, of which the component parts are the resistance of the leading wires and the resistance of the lamp filaments. The working resistance of a lamp is only to be got when it is lighted up. Its resistance cold is much greater than this.

If a pair of wires be set out, and one lamp be put

TABLE NO. II. FOR THE USE OF INCANDESCENT WIRESMEN.

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
Standard wire gauge.	Number of wires (if stranded).	Diameter.				Equivalent to solid wires.				Length and weight.	Weight and resistance.		Safe working current on basis of 1000 ampères per sq. in.	Approximate number of lamps usually run on the wires.	
		Of each single wire.		Of the strand.		Diameter.		Sectional area.		Pounds per 1000 ft.					
		In.	m/m.	In.	m/m.	In.	m/m.	Sq. in.	Sq. m/m.		Ohms per 1000 ft.	Ohms per lb.	Ampères.	45 to 60 volt lamps.	90 to 110 volt lamps.
22	1	·028	·711	—	—	·028	·711	·0006	0·397	2·37	13·167	5·54848	—	—	1
21	1	·032	·813	—	—	·032	·813	·0008	0·518	3·10	10·081	3·25229	0·8 to 1·0	1	1
20	1	·036	·914	—	—	·036	·914	·0010	0·656	3·71	8·427	2·27254	1·0 „ 1·5	1	2 to 3
19	1	·040	1·02	—	—	·040	1·02	·0012	0·810	5·34	5·852	1·09596	1·5 „ 2·0	2	3 „ 4
18	1	·056	1·22	—	—	·048	1·22	·0018	1·167	7·27	4·299	·59157	2·0 „ 2·5	2 to 3	4 „ 5
17	1	·064	1·42	—	—	·056	1·42	·0024	1·588	10·17	3·069	·30135	2·5 „ 3·0	3	5 „ 6
16	1	·072	1·62	—	—	·064	1·62	·0032	2·075	12·79	2·443	·19104	3·0 „ 3·5	3 „ 4	6 „ 7
15	1	·080	1·83	—	—	·072	1·83	·0040	2·626	15·69	1·991	·12679	4·0 „ 4·5	4	7 „ 8
14	1	·092	2·03	—	—	·080	2·03	·0050	3·242	20·85	1·498	·07186	5·0 „ 5·5	5 „ 6	8 „ 9
13	1	·104	2·34	—	—	·092	2·34	·0066	4·287	27·32	1·144	·04187	6·0 „ 7·0	6 „ 7	10 „ 12
12	1	·116	2·64	—	—	·104	2·64	·0085	5·480	35·96	·869	·02416	8·0 „ 9·0	7 „ 8	14 „ 16
11	1	·128	2·94	—	—	·116	2·94	·0105	6·774	43·59	·717	·01645	10·0 „ 11·5	9 „ 10	16 „ 18
10	1	·144	3·25	—	—	·128	3·25	·0128	8·302	54·35	·575	·01058	12·0 „ 13·5	10 „ 11	18 „ 20
9	1	·160	3·65	—	—	·144	3·65	·0162	10·50	66·30	·471	·00711	15·0 „ 17·5	12 „ 14	24 „ 28
8	1	·020	4·06	—	—	·160	4·06	·0201	12·97	82·41	·379	·00460	20·0 „ 22·5	16 „ 20	35 „ 38
25	3	·024	·508	·042	1·07	·034	·863	·0009	0·585	—	—	—	—	—	—
23	3	·028	·609	·051	1·29	·042	1·006	·0014	0·893	—	—	—	—	—	—
22	3	·02[illegible]	·711	·059	1·50	·049	1·24	·0019	1·216	—	—	—	—	—	—
25	7	·020	·508	·060	1·54	·053	1·35	·0022	1·423	—	—	—	—	—	—
23	7	·024	·609	·072	1·83	·064	1·62	·0032	2·075	—	—	—	—	—	—
22	7	·028	·711	·084	2·13	·075	1·90	·0044	2·849	—	—	—	—	—	—

across their far ends, the resistance of that circuit will be that of the wire added to that of the lamp. If another lamp be placed across the wires, the resistance of the circuit falls considerably, because a fresh additional path has been opened to the current. If three lamps be used it falls still more. The greater the number of lamps across the wires the less the resistance. In this way the resistance due to lamps is easily obtained by dividing the resistance of one lamp (in ohms) by the number of lamps.

$$R_3 = \frac{\text{Resistance of a single lamp, hot.}}{\text{Number of lamps in parallel circuit.}}$$

In *series-parallel* the resistances of the lamps will nearly follow the same rule. If two lamps in series are to cross the mains, they may be treated as one lamp with their resistances added together.

Wire Gauging.—The gauge of a wire is an important point. If it vary from the dimensions calculated for, it may easily lead the wiresman astray. The necessity for actual measurement as a check upon the reputed gauge of a wire has been of late forced upon the attention of engineers. There is now in this country but one table of gauges—that authorised by the Board of Trade and known as the standard wire gauge, adopted, as to the required numbers, in the tables given in this book.

It is very convenient to carry a pocket gauge of sufficient range and *accuracy* to cover the requirements of ordinary wiring. Several of these have of late been introduced, to meet a demand which is doubtless increasing. One of the best of the improved guages is represented in Figs. 54 and 55, which shows the actual size of a very portable and accurate form

patented by Mr. Trotter. This little gauge is provided with four scales. The standard sizes are given on the scale marked *S.W.G.* The scales marked *inch* and *millimetres* give the diameters of a wire in decimals of an inch and millimetres respectively, both being furnished with verniers. Each has one scale with an arrow head and one without. The latter is the scale proper, the former is the ver-

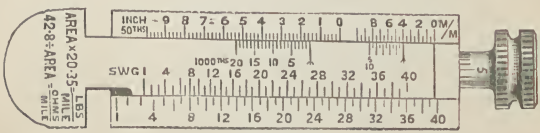

Fig. 54.—Trotter's Wire Gauge. Back.

nier. The arrow head points to the graduation on the scale from which the approximate reading is taken. The first decimal figure is read on the scale by the direct indication of the arrow head. It will then be found that one of the graduations of the vernier coincides with one of the graduations of the scale, and the remaining figures required to complete the reading

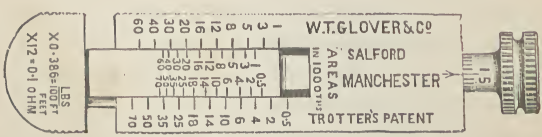

Fig. 55.—Trotter's Wire Gauge. Front.

are the numbers which correspond to this graduation, counting from the arrow head. The instrument is opened by turning the screw to the right. The wire to be measured is placed between the jaws and nipped tightly. The area of circles may be read upon a scale upon the back of the gauge. The area of a wire, once known, gives at once the capacity of that wire for

carrying a current. It is understood that high conductivity copper wire is alluded to, and that some such constant as 1000 ampères per square inch sectional area is used.

The gauge represented in Fig. 56 is an ordinary pocket hole or gap gauge, provided with apertures for all the usual sizes employed in wiring. It may be well to note that standard gauge copper wire, which is afterwards *tinned*, will read a fraction of an inch larger than standard gauge. Before measuring a wire all insulation should be carefully removed.

Tests for Conductivity of the Wires.—In fitting up a

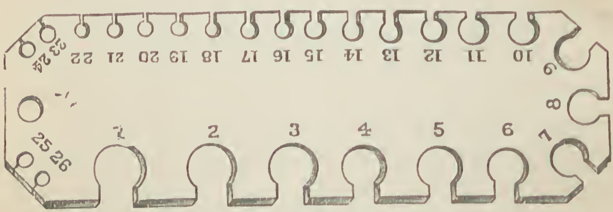

Fig. 56.—Gap Wire Guage.

large installation specimens of the conductors to be used should be tested for both conductivity and resistance. Each sample should not be less than 100 ft. in length. Each length, if intended for damp situations, should be immersed in a tub of water for at least 12 hours. The wires should then be tested by the aid of the testing box and figures given at p. 76. The resistance of each length should not exceed that given opposite to its gauge in the preceding table. The insulation resistance must depend upon the nature of the covering. If the wires are "best" insulated, in gutta-percha and tapes, they should show an insulation resistance of 20 meg-ohms per length.

Nature of the Insulating Covering.—The commonest insulated wire that can be safely used for electric light branch wires is coated as follows:—

(1) Tinned copper wire, conductivity 95 per cent. One coating india-rubber; braided with cotton and coated with preservative compound. Such a wire is unfitted for immersion in water, or for work in damp situations.

(2) Tinned copper. One coating cotton; one coating india-rubber; one coating felt; braided cotton and preservative compound. Such a wire is adapted for more exposed work.

(3) Tinned copper. One coating cotton, saturated with paraffin wax; one coating pure india-rubber; another coating cotton tape; braided and coated with preservative compound. This is "good insulation" adapted for damp situations.

(4) The same as above, with two coatings india-rubber.

(5) Vulcanised insulation, consisting of vulcanising india-rubber; one coating rubber-covered tape, and the whole vulcanised together and coated with preservative compound.

(6) The same as above, with a heavy braiding over all.

(7) Highest class. As above, with a covering of *lead* over all.

(8) Twin-wires, consisting of several fine wires, *e.g.*, 100 No. 40 stranded together, insulated separately, braided in pairs, for flexible conductors. These are used for portable lamps. The exterior covering is in silk, mohair, or cotton.

One rule should be followed by the electrician responsible for the success of the wiring—to use the best

class of insulation the nature of the case will permit, and to avoid having the wires too fine.

Switching Arrangements.

In planning the wiring of a building the main and lamp switches should be marked off on the plan. It is impossible to say how many switches should be fitted to a given number of lamps, unless the conditions be known. In house wiring it is convenient to provide a double main switch on the house side of the meter, and a switch to each lamp fitted. In electrolier work, where all the lights would be required at one time, a single switch for that group will answer.

It is neither necessary nor usual, as with gas, to fix the switches close to the lamps, especially when these are overhead. It is more convenient to furnish the means for lighting and extinguishing either near the doorway, as in hotel bedrooms, or near to the fireplace, as in drawing-rooms. Each case must be made to decide for itself. There is one point, however, that is worth considering carefully; it is a great saving of labour to locate switches and cut-outs (safety fuses) together; and it is an advantage to keep the fuse as near as possible to the root of the wire supplying the lamp.

Main Switches.—These are fixed at the root of the system, or at the root of each branch circuit, according to the nature of the case. There are many patterns in use, and we can only notice one or two of them. One of the most efficient of the double break type is represented in Fig. 57, which shows Drake & Gorham's main double ring-contact switch. The cross-arm, provided with insulated handles, swings upon

the central staff. The contact between it and the terminal rings shown is effected by slitting the ring, so providing a spring clip, into which the curved end of the cross-arm enters. Fig. 58 will serve to make this

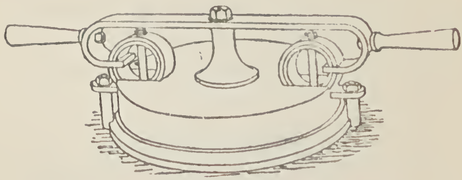

Fig. 57.—Drake & Gorham's Ring Contact Switch.

clearer. The ring is made in two or more parts, which gives it elasticity, and certainty of contact, as it wears away, is kept up by adjusting the lock nuts. This method of getting a tight sliding contact of large surface has been applied by the same inventors to a large variety of switches, some of which are represented upon the main switch-boards illustrated further on. Such switches are invariably mounted upon incombustible bases, of which perhaps the best is slate. Their main function is to provide perfect continuity when closed, and perfect safety from creating an arc, and so setting up a fire, when opened. Fig. 59 represents one form of Woodhouse & Rawson's double-break switch.

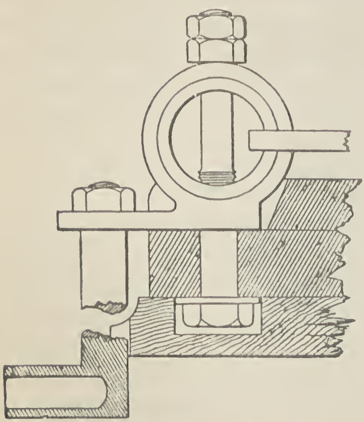

Fig. 58.—Ring Contact, Section.

Double-pole main switches are different from double-break switches inasmuch as they are constructed in duplicate—two switches in one, so that by one movement of the handle both leading and return wire are cut off from the circuit. Instead of opening the two wires of one circuit a double-pole switch may be used to open the positive or negative wires of two separate circuits.

Of late a good deal of objection has been raised by

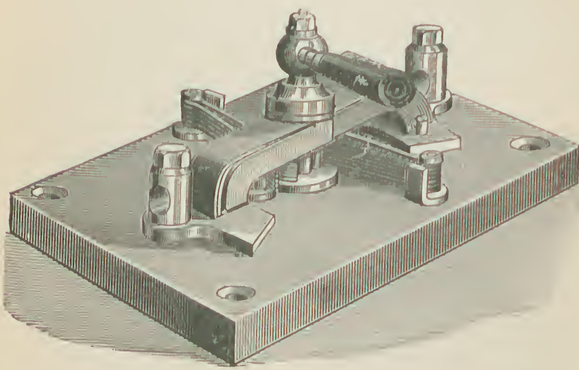

Fig. 59.—Woodhouse & Rawson's Double-break Switch.

fire office authorities and others against the practice of carrying wires belonging to the same circuit so close together, as is frequently necessitated by the use of double-pole switches. Any objection of that kind may, however, be easily met by providing two single switches, one upon each wire, a sufficient distance (several inches) apart, or by the simple expedient of providing sufficient space upon the double-pole switch itself. There can be no doubt that a double-pole switch is a great convenience. Fig. 60 represents Mr. Hedges' device for this purpose, which is

now extensively used in house lighting in the metropolis. A and A′ are a pair of sprung contact discs, bearing with sufficient pressure upon the polar pieces B B′. The base is incombustible. The main cable connections are made into the set-screw sockets as

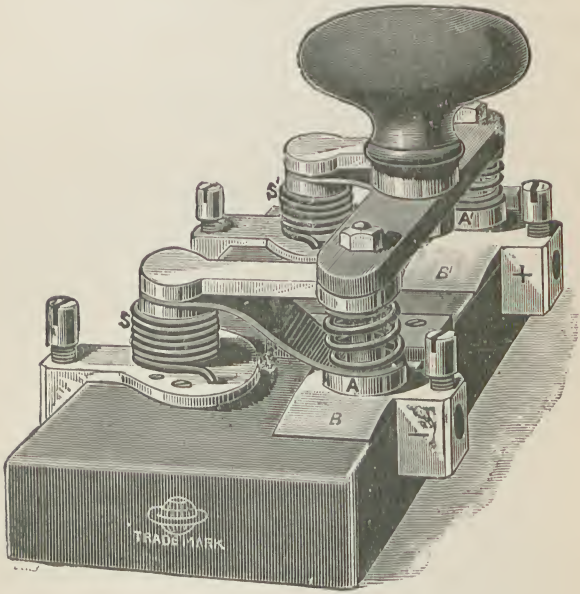

Fig. 60.—Hedges' Double Pole Switch.

shown at + —, and the branches from the opposite side.

Multiple-Way Main Switches.—Main switches may be broadly regarded as effecting three changes: (1) Cutting open and closing one wire of a circuit—or, in other words, "off and on" switching; this class of single-wire switch is made both with a "single break" and a "double break," as shown in

Fig. 59. The double break divides the spark at breaking circuit, and will suffer less than a single-

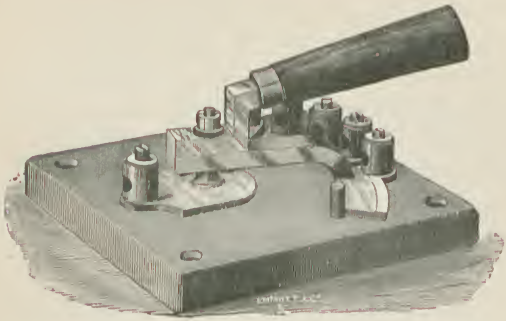

Fig. 61.—Woodhouse & Rawson's Multiple-way Switch.

break switch from burning of the contact surfaces. (2) Cutting open and closing the two wires of a circuit,

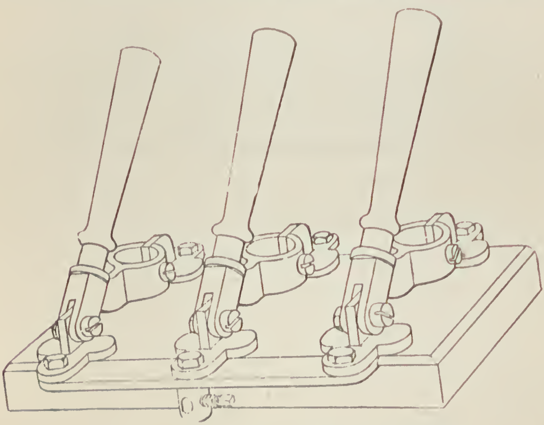

Fig. 62.—Ring-contact Multiple-way Switch.

called a *double-pole* switch. This variety severs the mains completely from the branches. The importance of this will be discerned when it is pointed out

that in the event of a bad *short circuit to earth* in one of the branch wires, merely severing one wire rom the mains would not necessarily stop the leakage, while severing the two cuts off all possibility of main current reaching the branches. (3) Multiple-way, or distributing switches. These are arranged in a variety of ways. The simplest form is represented by a central contact connected to the positive main, having a lever moving at will on to any one of several branch line

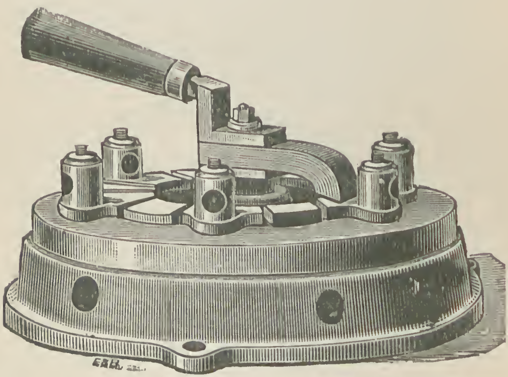

Fig. 63.—Woodhouse & Rawson's Accumulator Switch.

terminals, so as to throw the main current into any required wire. The switch may of course be elaborated to any degree, so as to lead the main current into any number of wires, according to the nature of the case. Figs. 61 and 62 show two forms of this description of switch, in the first of which Woodhouse and Rawson's multiple contact plate system is employed; the contact being given by a number of springy slips of gun-metal or brass, an arrangement which ensures a good deal of bearing surface between the two contacts. Fig. 63 is a form used for placing accumulators

in and out of circuit during charge or discharge. The short-circuiting of a cell is obviated by a coil of wire placed upon a vulcanised fibre plate below the slate base. It may be pointed out that if a switch carrying a heavy current have but a small contact, great heat and ultimate burning may be set up at that point. In the selection of switches, especially main switches, only those furnished with incombustible bases of sufficient thickness to retard the passage of heat should be used.

Branch Line and Lamp Switch.—These have been produced in great variety. The simplest kind in use merely forms a metallic touch, connected to the leading wire, and so arranged as to throw the current into the branch by contact. This is by far the most common variety of switch. It frequently is found with a great defect, which is worth careful consideration before fitting switches to be manipulated by ordinary people. A common switch, if turned partially but not wholly off, may serve to extinguish the lamps, but at the same time may be in partial contact sufficient to set up an arc there, or a fusing heat. This is he worst kind of switch possible for fitting into nouses. The difficulty can be overcome by fitting the movable lever with an "overthrow" spring, the function of which is to rapidly push open the switch as soon as it is started by hand, a device which renders "arc-ing" impossible. This re-acting spring device has recently been considerably improved upon in the Woodhouse & Rawson switches, and in those of several other makers. An "overthrow" spring may possibly be resisted by the hand of the person opening the switch long enough to form an arc and burn the switch. Such a contingency is met by making the

little handle free upon its arbor, so that when the switch is started once it is thrown fully open by the spring independently of the handle; *e.g.*, even if the handle be held firmly after starting the switch, it will spring open and prevent "arc-ing."

These switches are furnished with channels for the connection of the wires from the back, and with the

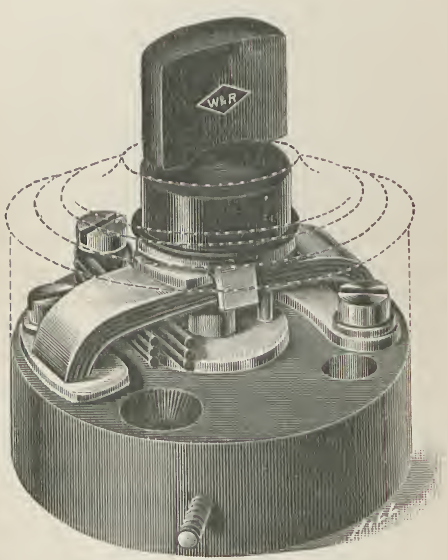

Fig. 64.—Branch Line or Lamp Switch.

necessary screw-holes for their fixing. They are usually protected by a cover of porcelain, or wood, of a shade and style of ornamentation to suit the colouring of the apartment in which they are placed. Fig. 64.

Combined Switch and Cut-out Fuse.—A very useful form of switch is that in which a fuse is fitted, as represented in the front of Fig. 65. The fuse usually

consists of a slip of tin, or alloy, which is easily re-

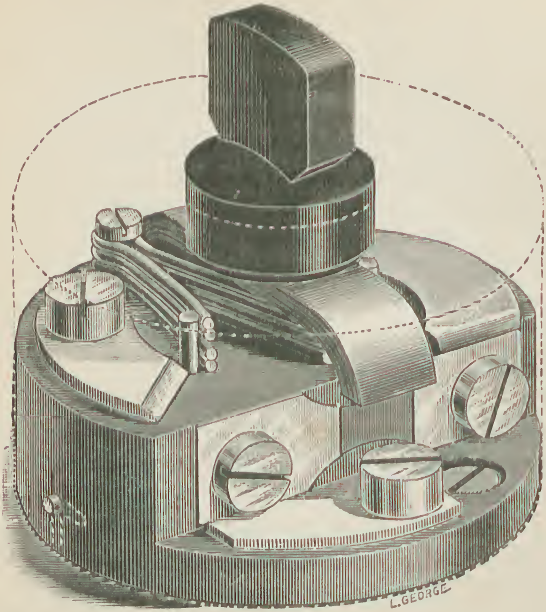

Fig. 65.—Switch and Fuse combined.

placed when accidentally burnt by too heavy a current. These combined switches are likely to come into general favour, reducing as they do the labour of fitting fuses.

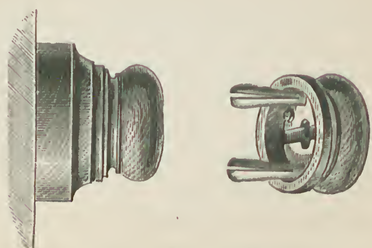

Fig. 66.—Wall Connection.

When a wall plug is provided for the flexible leading wires of a portable lamp, a duplex plug connection, as represented both in

position and separated in Fig. 66, is generally employed.

Plug and Removable Key Switches.—A plug switch is merely a metal plug, as used in resistance coils, which is inserted or withdrawn to make and break contact. Key switches are those opened and closed by a separate key, which is easily removed and carried about.

Reversing Switch.—The ingenious device shown in Fig. 67, which is due to a French electrician, enables the switching of a lamp to be effected from two points, as either end of a room. The diagram explains itself.

Capacity of the Switch.—Switches, whether for main or branch work, are said to be made to carry so many ampères—in the case of branch switches this would be approximately as so many lamps. A wide margin of carrying capacity is generally allowed. The main provision to insist upon is perfect contact, insulation, and incombustibility.

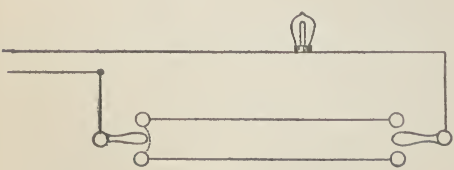

Fig 67.—Reversing Switch.

Main Fuses and Cut-outs.— A safety fuse is a device to prevent an accidental abnormal current from forming in a circuit. If a current greater than the circuits in a house were designed to carry were to pass through them, the points offering greatest resistance would speedily become red-hot. and fire would probably ensue. The main object, then, of a safety fuse, or cut-out as it is frequently called, is to prevent accidental overheating.

When a small portion of a circuit is composed of *very fine* copper wire, it will break at that point as soon as the current is raised sufficiently high to melt the copper. Perhaps the best material for a fuse is copper, but it has one great objection—its high fusing point. It is usual to employ an inch, or thereabouts, of tin, or tin-lead alloy wire; and in respect to gauge, it is a common practice to employ a wire one size finer than the copper circuit wire—*e.g.*, a 16-gauge copper wire

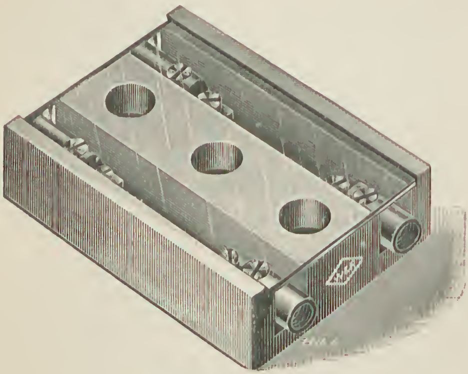

Fig. 68.—Main Fuses.

would be protected by an 18-gauge tin wire. Main fuses inserted at the root of house mains take several forms. One of the most convenient is the W. & R. double-pole fuse, represented in Fig. 68, consisting of a slate double trough so fitted that it may be conveniently screwed to wall or other fixture. The wires are led to the metallic plugs, which are fitted with screws for their reception. Between the plugs short lengths of lead or tin wire are fixed, and the whole is covered by a glass cover. Thus any accident to the fuses can be detected and the fusible wire replaced.

The capacity of the fusible plate is usually indicated upon it in ampères as shown in the diagram (Fig. 69) of Hedges' main fuse. The fuse plate may easily be removed and replaced by others (Fig. 70).

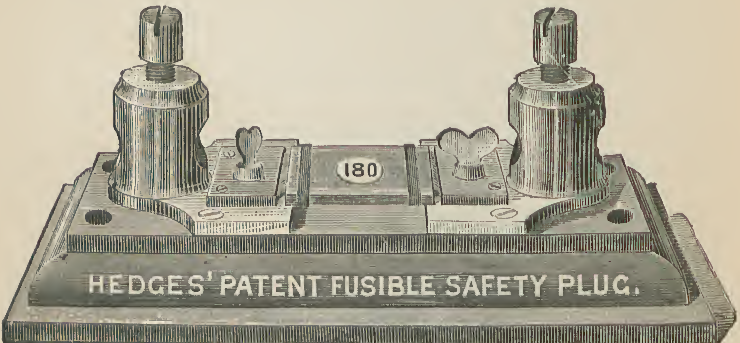

Fig. 69.

In many systems plugs of lead or fusible alloy are used for this purpose; in others merely a loop of lead wire is employed. There is one certainty in the use of a good fuse: if it be fixed close to a dynamo it will always burn up long before the copper wires are hot enough to injure the insulation of the machine. A paper by W. H. Preece, F.R.S.,* gives several deductions from experiments upon the fusing of different metals under the current.

Fig. 70.—Safety Fuse Plate.

The following refers to copper and tin lead alloy, two substances very much used for fuses :—

* Proceedings of the Royal Society. Vol. XLIV. March, 1888.

Standard wire gauge.		Copper wire fuses at ampères.		Tin-lead alloy wire fuses at ampères.
14	..	231·8	..	29·82
16	..	165·8	..	21·34
18	..	107·7	..	13·86
20	..	69·97	..	9·002
22	..	48·00	..	6·175
24	..	33·43	..	4·300
26	..	24·74	..	3·183
28	..	18·44	..	2·373
30	..	14·15	..	1·820
32	..	11·50	..	1·479

The fusible alloys generally employed for making safety plugs are usually more strictly amalgams in the case of the softer plugs. These are made from Arcet's metal, 9 parts, mercury, 1; and fuse at about 50° C. Harder plugs, melting at 210° Fahr. (just under the heat of boiling water) are made of tin, 3; lead, 5; bismuth, 7. A useful fuse for wires hung bare, where a good deal of heat may be allowed with safety, is made from tin, 1; bismuth, 1; it fuses at 285° Fahr.

Fusible Plugs and Branch Fuses.—The usual safety plugs are marked with the *number of ampères* of current they can carry without fusion. They are also, in rare cases, marked in "lamps," but this practice is extremely misleading. If marked in lamps, 16 candle lamps will probably be meant in most cases. Since the function of a safety plug is to protect the circuit at whose root it is fixed, it has no reference to lamps. The ampères in that circuit may approximately equal

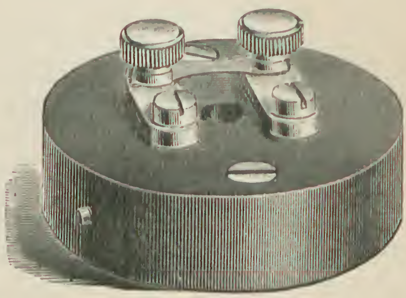

Fig. 71.—Branch Fuse.

the number of lamps, or they may not, according to the voltage of the lamps (*e.g.*, 50-volt lamps might take ampère, while 100-volt lamps would take ·5 ampère). One of the simplest forms of fuse plate is represented in Fig. 71, where milled nuts are provided for replacing a burned out connection.

Messrs. Patterson & Cooper issue a convenient and substantial form of fuse upon a slate base, represented in Fig. 72, in which a flat foil is used as in Hedges' fuses.

Particular Observation Respecting Fuses.—The inser-

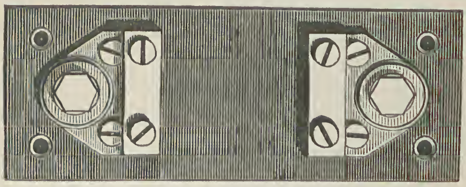

Fig. 72.—Main Fuse Plate.

tion of a number of fuses into a system of circuits may render that system a very safe one as far as overheating by accidental abnormal currents is concerned. But the multiplication of fuses may easily become a source of danger instead of safety. Each fuse implies a break in the wire and a pair of con nections. Unless the connections are honestly thorough they become a source of trouble. Every fresh connection is a fresh weak point in the circuit. It is essential to so make the connections that each has a carrying capacity greater than the wire itself, and is unquestionably sound. A carelessly soldered connection may heat very quickly. It may at any time break apart and set up an arc, so igniting dry woodwork. Besides theconnections the plugs them-

selves, if plugs be used, may have bad connection in their sockets. Every plug should be examined previously to being inserted into the circuit.

Fuse Boards. — For reasons stated above many electricians will not permit the distribution of fuses throughout the system of house wiring. In such cases it is considered safer to assemble all the fuses upon a fuse board (Fig. 73). The base or backing of this "board" is of slate, and the terminal blocks of brass. The figure represents a fuse board for eight circuits. The connection to the positive main is made with the central screw, and the current is thus distributed into eight paths. The fuses themselves, shown by the light lines between the lower and upper terminals, are either of lead wire or of strips of alloy. It is much easier to ensure good connections upon such a grouped system of fuses than in a distributed plan. But the use of fusible wire is difficult and uncertain, unless precautions be taken. The wire must either fit the terminal blocks very tightly, so as to ensure good contact without much screw pressure, or a piece of copper wire must be soldered to the end of the fuse for connection with the terminals. Al-

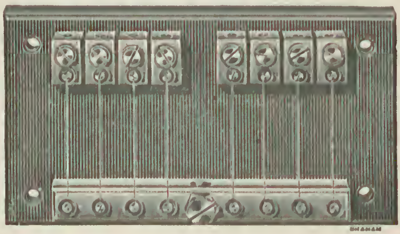

Fig. 73.—Fuse Board.

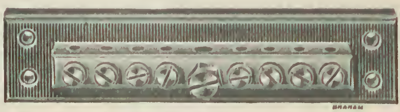

Fig. 74.—Terminal Block.

though the fuse boards are usually placed only in the positive main, with a plain "terminal block" (Fig. 74) upon the return, it is still better to have a fuse board upon both poles of the main. The use of terminal blocks of this pattern is extending. They obviate the necessity for large, coarse main or ter-

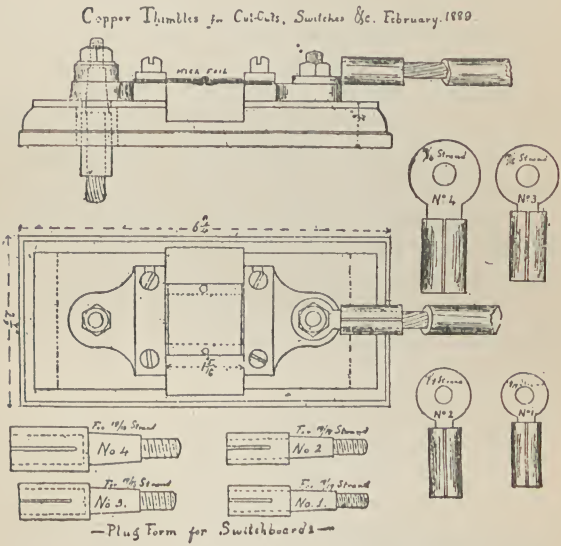

Fig. 75.—Hedges' Fuses for Switch-Loards.

minal joints, and greatly facilitate examination and testing of the circuits.

Mr. Hedges has devised a form of fuse for switch boards (Fig. 75), which would appear to offer several advantages, providing as it does means of rapidly connecting the main cables. The fusible foil bridges over a gap as represented.

Mr. Scott has devised the handy fuse represented in Fig. 76. It consists of a fine wire, run over the

surface of insulative material, forming a kind of conductive plug which may easily be slipped into position in the base. This plug provides the "one inch break" generally required by the fire offices.

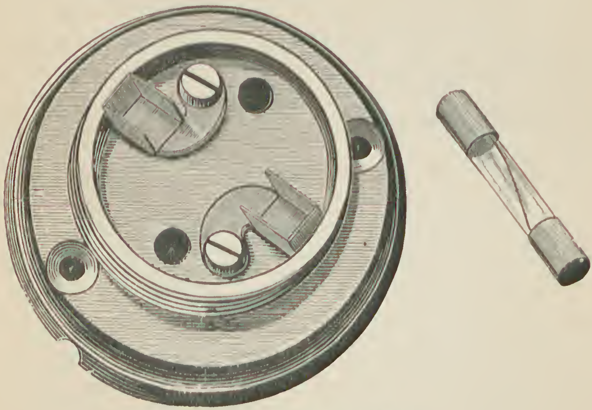

Fig. 76.—Scott's Fusible Plug.

The Lamps and Fittings.

Area Lighted.—A 16 candle-power lamp is usually fixed for every 100 square feet around the lamp, the latter being raised from 6 to 10 feet above the floor line.

Light Absorbed by Glass Envelopes.—When the lamp is covered by a globe the following percentages of light are lost for the different classes of glass: Clear glass, 10 p. c.; ground glass, 35 p. c.; opalescent, 50 p. c.

Incandescent Lamps in General Use. — Various makers' productions are in use. The most widely known are the Edison & Swan's lamps. They range, according to the nature of the filament, from one candle power to 1000 or more, when fully incan-

desced. The most common powers are the 8, 10, 16 and 20 c. p. lamps. For house lighting 10 and 16 c. p. lamps are deemed sufficient. Of the two the 16 c. p. is probably the more widely used.

Electromotive Force and Current of the Various Classes.—The lamps in general use absorb approximately the following:—

	Volts.		Ampères.		Volts.		Ampères.
8 candle-power takes from	10	..	2·8	to	120	..	0·3
16 ,, ,, ,,	15	..	3·7	,,	160	..	0·4
25 ,, ,, ,,	40	..	2·2	,,	120	..	0·7
50 ,, ,, ,,	50	..	3·5	,,	120	..	1·4
100 ,, ,, ,,	50	..	7	,,	120	..	2·9

But it is impossible at the present time to lay down a rigid rule. The 8 c. p. lamps are very generally run at 10 c. p., and the 16 c. p. at 20. It is more economical, as far as current is concerned, to run them above their nominal value. But the life of the lamp is thereby shortened. The "life" varies, and depends almost entirely upon the supply—its constancy, regularity, freedom from fluctuations and so on. The average has been placed at 1000 hours, but many lamps have been known to burn 5000 hours. The life chiefly depends, no doubt, inversely upon the *intensity* of the incandescence.

Nature and Description.—The incandescent lamp is now so well known that it appears unnecessary to describe it. It may be regarded, however, as a short length of very fine conducting filament of graphite carbon, usually curved into the shape of a hairpin, and mounted within a pear-shaped glass envelope, from which the air has been very carefully exhausted. The two ends of the carbon thread are put into communication with the exterior of the glass by two fine wires of platinum, sealed into the glass (Figs. 77 and

78). The lamps need careful handling, as the carbon filament is very brittle and easily broken. If the glass be broken, the lamp is destroyed. If this rupture should occur while the current is passing through the lamp, the carbon thread will be at once consumed. The filament is caused to glow by a small portion of current being impelled through it under the "pressure" or electromotive force set up by the dynamo. The higher this pressure the less current

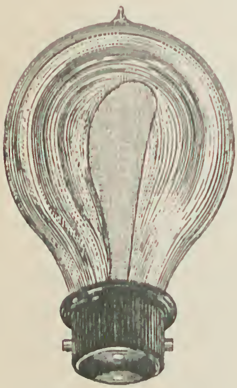

Fig. 77.—Edison Lamp, B.C. pattern.

Fig. 78.—Swan's Lamp, B.C. pattern.

per candle power is required, so that it is economical, as before stated, within reasonable limits to work lamps at a high pressure. The working pressure, measured in volts, is always marked upon the lamps. But, as in the case of various other "nominal" working figures, these are frequently exceeded.

Blackening of the Bulbs.—This cannot at present be avoided. When a lamp has been in use a few hundred hours the interior of the glass appears to get coated with a fine black powder—probably, particles

of carbon from the gradual destruction of the filament. This blackening impedes the light, and it becomes a question whether it is economical to run such blackened bulbs longer after a certain percentage of light has been so cut off.

Current Absorbed by the Lamps.—The current varies, as before stated, with the "pressure" at which the lamps are worked. It is usually expressed in "watts." A lamp is said to take so many watts per candle power. The best lamps take from 3·5 to 4 watts per candle, under ordinary pressures. 746 watts are called an electrical horse-power, and from 45 to 60 watts will be absorbed by an average 16 c. p. lamp. Roughly, from 10 to 14 of such lamps are usually obtained per mechanical horse power expended upon the dynamo. The balance is usually lost in the resistance of the circuits.

The Economical Efficiency of the Lamps.—With regard to the question, *at what pressure it is economical to run the lamps*, seeing that a high pressure shortens their life, but calls for less electricity per candle power, an interesting paper was read at the American Institute of Electrical Engineers by Mr. Howell, electrician to the Edison Lamp Company, April, 1888.

The paper embraced a series of curves, showing the performance of lamps of various costs, candle powers, efficiencies, and with various periods of life. The general deduction from the numerous experiments that had been made to determine this point was that *the most economical efficiency of the lamps was attained when the cost of lamps was* 15 *per cent. of the cost of operating the entire electric plant.* In other words, if the lamp bills (renewals) were less than 15 per cent. of the total expense of the electric lighting, the pressure

imposed upon the lamps was too low. If the lamp bills exceeded 15 per cent. of the expenses, the pressure used was too high. It was also shown that if, for example, the lamp bills are only 10 per cent. of the whole cost, increasing the efficiency of the lamps by increasing their candle power does not reduce the total cost; but in order to attain that end the lamps must be replaced by others of the same candle power, but of higher efficiency. It is therefore clear that it is by no means economical to run lamps at so low a candle power that they will last beyond a certain number of hours. Instances are common of lamps having been run at so low an efficiency that they have lasted 5000 hours. It would appear that in this case it would probably have been better to burn out five lamps, each lasting 1000 hours.

Apart from the question of current wasted upon a lamp in the above way, there is the inevitable blackening of the bulbs to be contended against, as already spoken of. When this proceeds a certain way it is better to replace the lamp, even although its filament may have a good length of life left in it. It should, in fact, be treated as a broken lamp.

A "kilowatt" is 1000 watts. The kilowatt is frequently taken as a *unit* in describing the power of a dynamo. Thus a dynamo will be described as a "10-unit machine," meaning a dynamo capable of causing an electrical flow of 10 kilo-watts (10,000 watts).

The Board of Trade kilowatt-hour is the recognised unit of measurement of electricity supplied to consumers. It means a kilowatt maintained for one hour. Its selling price in this country varies from 6d. to 1s.

Fittings.—These may be roughly divided into sockets, or lamp holders, or connectors; brackets, or arms for supporting the lamps and pendants, and electroliers.

The sockets depend upon the connections provided at the lamp bulbs. These are arranged variously. The most common is a pair of metallic studs, fixed to the stem by means of a brass collar, and known as B C lamps in the trade. A common plan is to provide two small loops at the bottom of the bulb, and to hook them to the terminals in the socket to make electrical connection; called bottom loop lamps, or B L. The sockets are also made in the form of adapters, for use upon existing gas fittings, called G. F. adapter supplies (see "Gas Fittings," p. 196). The "contact" is made certain in various ways. The earliest plan was that of loops, kept apart by a spiral spring, and later by means of a bayonet joint (Fig. 79). The usual present device is arranged to come into contact by simply screwing, the details of which we cannot enter upon here.

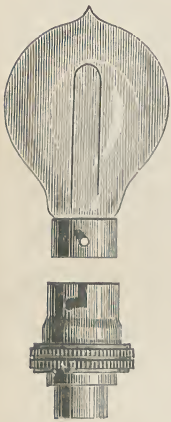

Fig. 79.
Edison Lamp, with bayonet joint.

Brackets are made in an immense variety of designs. They are very similar to gas brackets, but are generally arranged to throw the light downwards. Incandescent lamps being different from gas burners, inasmuch as they can be held in any position, afford great scope to the art-worker in the production of new and beautiful designs for brackets and electroliers. Flowers and fruit naturally suggest many ideas in this direc-

tion, and it is a common practice to make the lamp come in as a "bud," or the centre of a "bloom." or as the fruit itself. For such purposes the bulbs are frequently coloured.

A very convenient arrangement for students is represented in Fig. 80, which shows Mr. Hartnell's adjustable shade carrier, by means of which the light of the lamp may be projected in any direction, or at any angle.

Dispersion of the light is a subject which has occupied many minds, and there is probably nothing better

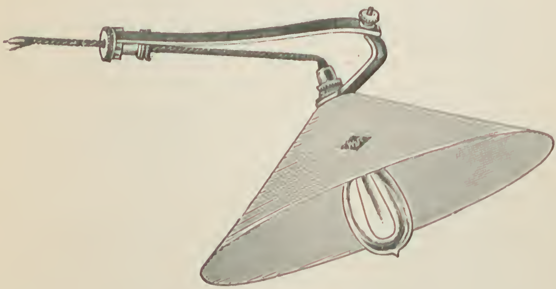

Fig. 80.—Hartnell's Lamp Reflector.

than reflectors for ordinary purposes. Mr. Trotter's application of dioptric shades appears to present some advantages in this direction. The shades are moulded from clear flint glass into innumerable little prisms, causing considerable diffusion of the light, while it obviates the glare of light direct to the eyesight. Fig. 81 represents one form of these shades, completely enclosing the lamp or lamps. The dioptric shades will no doubt prove useful for indoor arc lights.

Attachment for Portable Lamps.—Portable lamps, fed by a flexible twin wire, attached to a pair of poles fixed at any convenient point in the wall of a room,

are becoming very common. Since the leads are exposed to so much friction there is constant danger of short circuit in these leading wires. Hence the

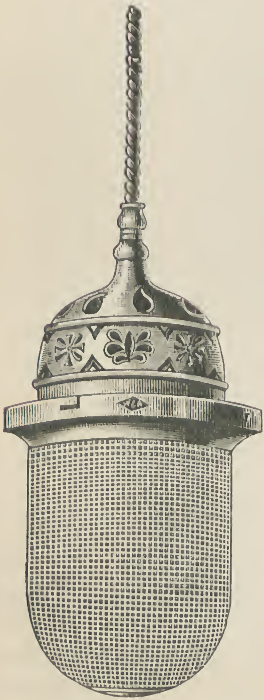

Fig. 81.—Trotter's Dioptric Shade.

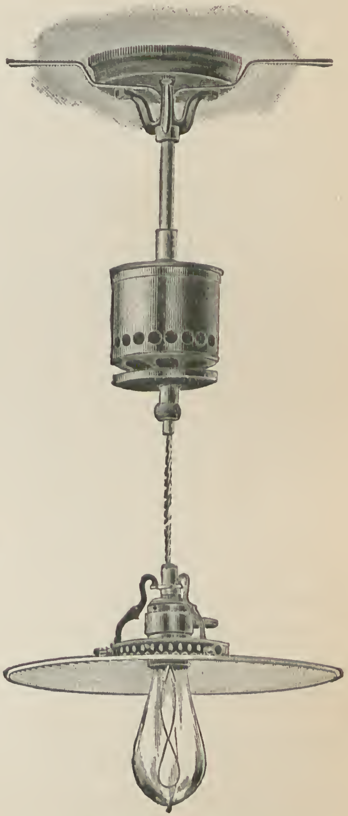

Fig. 82.—Pendant Lamp, with Reflector.

invariable practice of careful engineers to fit a fuse behind the wall attachment, where the flexible leads leave the branch wires. If accidental contact then

takes place between the leads, the fuse will give way before the danger extends to the wires themselves.

Telescope pendants have been devised for the electric light. Various plans have been suggested for he purpose of keeping up the *contacts* when the pendant is lowered or raised. One of the earliest ideas was to employ a flexible twin wire, running upon a spring reel, after the manner of a spring blind, the wire being used merely to feed the lamp. A later method employs a single sliding contact, consisting of a spring bearing upon an insulated metallic strip connected to the positive wire, the fitting itself being in contact with the negative pole. Various other devices have been tried which cannot be entered upon here. Fig. 82 represents a convenient reflecting pendant for either arc or incandescent lamps, issued by Messrs. Laing, Wharton, & Down.

Methods of Running the Wires.

"*Rule of the Road" for Leads.*—It may be as well to quote here the alliterative rule generally observed by wiresmen in running leading wires: "Leads left, Returns right," when laid upon a floor or ceiling; when placed upon a wall, horizontally, "Leads low, Returns raised."

Red insulation is generally used for leads (positive wires) and *Black* insulation for returns (negative wires). It may be observed here that a good deal of complaint is being raised that the *red insulation is inferior to the black*—this, if insisted on by makers, will speedily result in the black being used for leads, and the red for returns. For rules to find the direction of the current, see p. 24.

Cleat Wiring.—This means uncovered wires, run as neatly as possible upon walls, flooring, and ceiling, and held in place either by "cleats" (Fig. 83) of wood, with a double groove, or by leather loops.

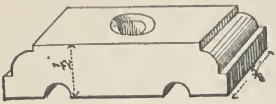

Fig. 83.—Double Wire Cleat.

Cleat wiring, although unfitted for house work, is eminently adapted for theatre stage-wiring, for mills, and in every situation where the appearance of the bare wires would not be objectionable.

It is *very desirable* to expose the wires to view it possible. It prevents moisture from accumulating, renders the detection of leakages and faults comparatively simple, and compels the wiresman to observe that the proper distance is maintained between the wires. In mills, where dust is generated, it is apt to settle *very much* upon wires carrying continuous currents, but not upon those carrying alternating currents. When a length of wire is run it should always be stretched taut, from point to point, and securely cleated down. Cleats may be required, according to the situation of the wires, from every three to every six feet of run.

Crossing Cleats have been devised for enabling one pair of wires to cross over or under another pair without danger of contact. They are usually made in glazed earthenware, but more frequently extemporised by the wiresman himself upon the spot. A wooden cleat of this kind merely consists of two cleats placed across each other. It is usual to put in a square of vulcanised rubber between the cleats. The single-wire crossing pieces are usually made in earthenware, and lead one wire, as an arch, over the other. The

distance between the wires so crossed should *never be less* than an inch. The main provision is certainty of separation. It must be impossible to press or bend the wires so crossed into contact with each other.

Cleats should be screwed, not nailed. The screws must not touch the insulating covering of the wires.

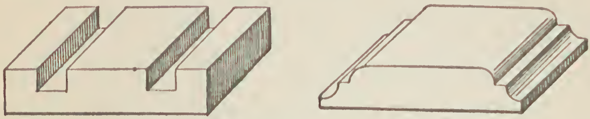

Fig. 84.—Double Wire Casing and Cover.

Brick walls must be pierced with chisel and hammer, to allow of the driving in of a block of wood upon which to screw the cleat. The wood should be driven in so that its grain is across the path of the screw, otherwise the latter may be easily pulled out. The cleats themselves are made from *hard* wood, with semicircular or square channels.

Casing and Moulding Wiring.—This is by far the most common method at the present time for house work. It implies concealed wires, but yet accessible in a case of need. The casings are merely continuous cleats. Fig. 84 is an example of a section of plain channelling with its moulded cover, and Fig. 85 of a more elaborate pattern. Figs. 86 and 87 represent single-wire mouldings for a cornice or angle and an open situation respectively.

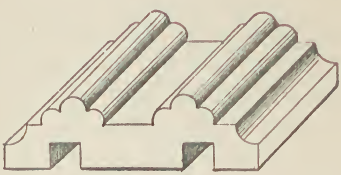

Fig. 85.—Double Wire Moulding.

Casings are usually made in soft wood, but for

special purposes are produced in immense variety by Mr. Elliott, of Newbury, from whose designs the above engravings are taken. Mouldings will necessarily be selected to suit the ornamentation of the rooms, or to taste.

There are several methods of casing the wires. But all that is necessary is to run the wires taut from point to point, and to securely screw the moulding upon them. Some wiresmen are more particular in their method, and take pains to loop down the wires upon the walls first, the requisite distance apart, and to apply the casing merely as a covering or protection. The channelling, which is double, as Fig. 84,

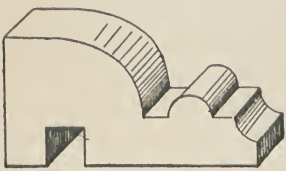

Fig. 86.—Cornice Moulding.

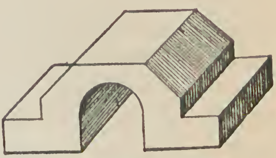

Fig. 87.—Single Wire Casing.

is first screwed to the walls or floors, and the cover laid upon it after the wires are run in the grooves.

The object of mouldings is of course to conceal the presence of wires altogether, and numerous ingenious devices have been resorted to by artistic workmen to get wires to fittings and electroliers without breaking the plaster of the walls. In some cases the plaster is cut out in the path of the wires, and, after they are laid in a thin sheathing in the channel so obtained, a thin wooden cover is put on, and the whole re-papered or painted, forming complete concealment. Mouldings are frequently run above the wainscot, or in corners, or along the course of skirting boards. When wires have to be run upon a ceiling, and the place for

the lamp *cannot be reached from above*, a moulding must be run across; but it is usual in that case to give the ceiling a symmetrical appearance by fitting three other *dummy* mouldings, forming panels.

It is impossible to enter here upon the numberless devices resorted to for the purpose of concealing the wires, or at least giving their covers an artistic appearance. Each case must be made to decide for itself.

It is almost needless to enter upon a consideration of the wiring of buildings while in course of construction. Although the use of the electric light is spreading rapidly it will not for many years be allowed for in new buildings in this country, except in rare instances. Progress in England is extremely slow, and it is probable that houses will continue to be fitted for gas light long after that illuminant has been relegated in great part to the duties of heating and cooking.

If a general suggestion may be thrown out we may say that the architect should provide vertical tunnels in the brickwork, at least 8 in. by 12 in., communicating with each floor from top to bottom of the house. The tunnels should be boarded or wood-lined by the carpenters. That, with the provision of horizontal openings of the same size through partition walls, on the level of each floor, will form the only difference necessary between providing for gas and electricity. Ceilings will be reached from above, as in the case of gas-fitting. Brackets on walls will be reached from above or below by means of small tunnels formed behind the plaster. Gas-pipes are buried in the plaster, or cleated to the brickwork. This cannot be done in the case of electric light wires, and it is

doubtful whether it should be resorted to, even in the case of wires covered over all by a protection of lead.

Wherever wires are run in a building the adjacent woodwork must be dry, and conductors must in no case be affixed to, or laid in damp walls.

In running wires beneath flooring, and in other situations where the wires cannot be cleated down, it is important to ensure that they are "hauled taut" and well separated; in running concealed wires this precaution against accidental contact between the wires is more important than any other. Two wires must never be run through the same opening in a ceiling without the use of hard rubber separating-tubing slipped over each wire. The same is true of walls and partitions, where, if practicable, earthenware separating-tube should be used.

Are these Precautions Needful?—The questioner has only to read the rules laid down by the fire offices and the suggestions of the Institute of Electrical Engineers to find an answer. He must bear in mind that *although electricity is the safest illuminant ever used*, it consists of energy conveyed in wires, and that it will either manifest itself as light or as *heat*. If too much of it be forced through a thin conductor, that conductor will become hot, and it may become red-hot. If it can find a short path back to the mains *without passing through the lamps*, it will inevitably do so (as in two wires crossing). This will shortly—unless the insulating covering of the wires be very good—cause a contact and an electric arc, which may possibly give rise to fire. But when electricity is compared with gas, it is both easier to make it perfectly safe, and to provide *beforehand* for *leakage*. A

gas-pipe may leak and suffocate every one in a house; an electric wire, if it leak, would heat up its fuse, and *get cut off* from the supply. There is no such possible precaution in the case of gas.

A great deal of nonsense has been spoken of the dangers of electricity. Although it has been in extensive use as an illuminating agent in this country for at least ten years, it is difficult to point to a single authentic instance of damage due to it. As used in houses, at a pressure of one or two hundred volts, it is perfectly harmless to the person. The conductors are so insulated and protected by cut-outs that any accident that might cause a fire is rendered impossible. Provided then a conductor of sufficient size, so that its sectional area is from one to one and a half square inch for a thousand lamps (or from 1000 to 1500 ampères), and suitable fuses inserted at the root of each branch, danger is entirely out of the question. But a good deal of discreditable work in the form of wiring has been done by unscrupulous contractors. Insufficient insulation has been put upon the wires. These have been carelessly run. They have been loaded with current (possibly from 2000 to 4000 ampères per square inch), so that they were always hot when at work. They have not been protected by fuses at all. And thus, through general ignorance, many installations have proved unsatisfactory, and broken down after a time, the users returning in disgust to gas or candles. Happily this state of things is passing away. Well insulated wires are being introduced, having ample carrying capacity, and their distribution is now better schemed. Fuses are being employed with many other precautions. There is one leading maxim for a contractor putting in electric

light, and it is to avoid contracts that do not allow of the best class of material and labour being used throughout.

Tests during Wiring.—As suggested at p. 151, the general plan of the wiring must be taken upon paper, together with particular attention to such details as the positions of fuses and switches. During the progress of the wiring the leading hand should every day test each circuit as it progresses for continuity and crosses. He can find crosses or short circuits most easily by earthing all the distant ends of wires according to the directions given at p. 83. Continuity and freedom from short circuits having been ascertained, the final consideration in an installation of any considerable size is the resistance, both copper and insulation, of the circuits. Several hints as to these tests are given at p. 84, together with particulars of the instruments required. The tests should always be made from the dynamo, or from the point where the branch mains enter the house. In taking the copper resistance tests the ends of the far branch leads and returns must be twisted together, or connected with brass screw-junction pieces. All lamps must be removed. Every successive step in the testing must be made according to the plan of the wiring, which should be placed upon a wall near to the main switch-board. It is usual to take the insulation tests last. It may be of interest to state that a great deal of very good incandescent wiring has been done without taking either copper or insulation resistance tests. But in such cases the copper conductors have in every case been carefully selected to suit the distances at the outset. The insulation has been of the best, and the work in all its details

carried out under the eye of the responsible electrician. Testing, at best, is but the detection of possible careless work or unforeseen accident. Continuity tests cannot well be dispensed with. Insulation tests are essential aboard ship, or in mills, and in any situation where there is danger from damp or contact with wires.

Prof. Jamieson's Rules for Insulation Resistance of Electric Light Circuit.—In a paper read before the Institute of Electrical Engineers,* by Professor A. Jamieson, F.R.S.E., he gives the following formula relating to the insulation resistance which should exist in the best kind of installations of the electric light:—

Let R_I = the total insulation resistance of the whole or any part of the lamp circuits, or of the generator, in ohms;

K = a constant, $\cdot 1\ \Omega = \frac{1}{10}\ \Omega = 100{,}000\ \omega$ (100,000 ohms) found from actual tests of several well-erected installations;

E = E.M.F. of dynamo or installation in volts;

N_L = number of lamps (16-candle power) on each circuit or on the whole circuit, then

$$R_I = K\frac{E}{N_L}$$

The insulation resistance is therefore here taken to be *directly* proportional to the nominal E.M.F. of the dynamo, and *inversely* proportional to the number of 16-candle power lamps in circuit.

The Phœnix Fire Office rule puts the insulation resistance of different sized installations into tabular form, as follows:—

* Journal of the Institute, January, 1889.

Installations of	25 lights	. . . . .	500,000 ohms.
,, ,,	50 ,,	. . . . .	250,000 ,,
,, ,,	100 ,,	. . . . .	125,000 ,,
,, ,,	500 ,,	. . . . .	25,000 ,,
,, ,,	1000 ,,	. . . . .	12,000 ,,

This applies to continuous currents having an electromotive force of 200 volts and under, and implies a test taken at one operation over the whole installation.

It is, of course, well known that tests of insulation are the exception, and, unfortunately, not the rule. It should be urged that insulation testing is quite as important as continuity testing, and certainly more important than conductor resistance testing, especially aboard ships. If insulation tests are to be neglected, the greatest precautions must be taken in the matter of selecting well-insulated wires, and in running them in the safest positions. See also "Rules of the Institute of Electrical Engineers," p. 212.

Estimation of the Electrical Power Required.

All electrical work, in wires and at lamps, represents the expenditure of mechanical energy. The mechanical units of measurement cannot, however, be employed in calculations of the electrical work. The electrical units employed by practical engineers in estimating electrical work are named as follow :—

Volt.—The accepted unit of measurement of electromotive force, or the potential difference between the poles of a machine (very generally regarded as, and styled, "pressure"). This unit bears a certain relationship or proportion to the absolute unit of pressure, the physical significance of which is fully explained in most text-books of electricity. *Voltmeters*, showing at a glance the voltage of any electric source, are

generally graduated by means of a standard galvanic cell, the electromotive force (as volts) of which is constant and well known. Either the ordinary telegraph Daniell cell, the volts of which are approximately 1·07, or Clark's standard mercury cell (volts 1·434) is used as a standard of comparison. The electromotive force of any electric source (dynamo, accumulator, &c.) is really a potential condition, and cannot correctly be regarded as similar to head of water or other mechanical pressure. It may be regarded as the state of strain existing between the terminals of the dynamo *tending to set up a current.* If the current be allowed to flow the strain is at once relieved, so that in measuring the potential difference between the terminals the voltmeter (although connected across them) is of so high a resistance as to prevent the setting up of a sensible current. The volt is generally symbolised in formulæ by the letter E (electromotive force). It bears a certain practical relationship to the other units of electricity spoken of below.

Ohm.—Electromotive force or pressure cannot exist unless there be a certain *Resistance* to the flow of electricity. Every conductor offers a certain resistance to flow. This resistance is measured in terms of the unit named after the famous enunciator of the law of electric circuit, Dr. Ohm. Its physical significance and derivation are explained in most of the textbooks. The ohm is the resistance offered by a column of mercury 1 square millimetre in cross section and 106 centimetres long. 210 feet of No. 16 standard wire gauze copper wire, at a temperature of 60° Fahr., exhibits a resistance of one ohm, symbolised R (resistance).

Ampère.—The third factor dealt with by Ohm's law

is that of current, or flow. It may conveniently be expressed as the electric flow that would occur if a volt pressure were applied to an ohm of resistance. This current is called an Ampère after the celebrated French mathematician of that name. It is generally symbolised C (current).

The expression of these units brings us to the relationship they bear to each other. If, now, a volt of pressure be set up at the terminals of a dynamo, and a wire measuring an ohm be made to connect them together, the current flowing will be an ampère, as explained in other words above. The law is variously expressed

$$\frac{\text{Electromotive force in volts}}{\text{Resistance in ohms}} = \text{current in ampères.}$$

or the pressure divided by the resistance gives the current. The law may also be written—

$$R = \frac{E}{C}$$

or the resistance can be found by dividing the pressure by the current; or it may be expressed—

$$E = C \times R.$$

In different words, the current is directly proportional to the electromotive force exerted in, and inversely proportional to the resistance of, the circuit.

Relation of these Units to the Mechanical Power.—To set up a current through a resistance, energy must be expended; this is called Power, or Work. The unit of electrical activity in a circuit, bearing a direct relationship to the work of the steam-engine, is called a *watt* (746 watts = 1 electrical horse-power). The watt is really a volt-ampère. As an engineer speaks

of so many foot-pounds so does the electrician speak of volt-ampères, or watts. When it is required to measure the work done by a current in a wire or a lamp, it is necessary to ascertain the ampères of current flowing through it, and the volts of pressure impelling the current. The two numbers so found multiplied together gives us the activity or power in watts or volt-ampères.

For example, if it be required to determine the power expended in maintaining a certain number of lamps in a circuit, the voltmeter shows a pressure of 50 volts, and the ampèremeter a current of 15 ampères, multiplying these together gives the watts 750, which, divided by 746, the number of watts in an electrical horse-power, shows that the circuit is consuming energy of a trifle over 1 horse-power.

Again, the rule may be applied to a dynamo to ascertain its output. If the voltmeter shows 100 volts, and an ampèremeter 10 ampères of current flowing in the lamp circuit, the dynamo is yielding 1000 watts. This output is called, under the provisions of the Board of Trade regulation, a *kilowatt*, and if the power so expended be continued for an hour it constitutes a *kilowatt-hour*, which is the unit now used for electric lighting, in the same way as "1000 cubic feet" is employed for gas lighting. A machine yielding a kilowatt would be known as "a one-unit dynamo." The machine is supposed to run at a suitable speed, and to maintain the current for long periods without heating. The performance of the dynamo under these conditions is called its capacity. Such a one-unit dynamo would light about 20 lamps, each taking 50 watts. As lamps are now made each would probably give a light of 20 candle-power, the

watts per candle-power being 2·5. Such a machine would yield, according to the definition of the watt, 1·34 electrical horse-power.

The Electromotive Force (Pressure) Required.

For 50-*volt Lamps.*—The volts of pressure to be put upon the circuits will depend upon two conditions: (1), upon the voltage of the lamps, and, (2), the resistance of the circuits. In a small installation 55 volts should be ample when 50-volt lamps are used. This allows 5 volts for fall of potential due to resistances and for increased fall of potential due to increased current when all lamps are lighted, which is a large allowance. Five per cent. is usually considered a large allowance from dynamo to lamps and back. If the wiring be schemed according to the directions already given, it will cause a fall of pressure of about 2·5 volts for every 100 yards run. That is, if the most distant lamp be 50 yards away, 2·5 volts only will be lost in leads and returns.

For 100-*volt Lamps.*—These lamps are more economical to run than 50-volt lamps, but have not the same "life." The 100-volt lamp is very generally used in this country. An allowance of 100 volts, at least, is made for lamps, with the usual 5 per cent. additional for fall of pressure. The greater the number of lamps the greater the fall of pressure. This is due, as above explained, to the necessarily increased current. The fall of pressure of course is a characteristic of each installation, and cannot be exactly determined unless all the details of the wiring are known. Many of the first electricians scheme their wires on the basis for current of from 1000 to 1500 ampères per square inch

of section, proceed to run them, and make a voltage allowance after taking the resistances—by methods already given—first, with all lamps "off" and parallel wires temporarily connected at their far ends; secondly, with all lamps connected and terminal wires disconnected.

The Current (Flow) Required.

In estimating for wiring and lamps it is necessary to consider that we are arranging for the continuous consumption of *power*. If we spend as little money as possible upon copper conductors—just enough to keep them from overheating—we are arranging for the *maximum of waste* of power. The conductors should always be as large as possible, or as convenience will allow. This will ensure the minimum of waste on the wires. The suggestion of Sir William Thomson that *conductors should present an effective conducting sectional area of a square inch for each* 1000 *ampères* of current carried, is only a suggestion made for the protection of buildings from fire; it does not imply that 1000 ampères per square inch is the best proportion. Many installations are running at 1500 and 2000 ampères per square inch of section of conductor. At the latter current the copper would become warm and would tend to soften the insulation. At both volumes of current great waste of power is incurred in the conductors. The user of the electric light would speedily find that 500 ampères per square inch of conductor was a more economical system of wiring than any larger proportion. But, as above stated, in house wiring conductors are short, and must, from considerations of bulk, be kept thin, so that for such

work Sir William Thomson's rule is probably the best.

The current taken by lamps varies considerably for different lamps of the same nominal voltage and "watts per candle." The usual 50-volt lamps take approximately *an ampère each.* The ordinary 100-volt lamps of 20 candle power take approximately *half an ampère each.*

It will thus be discerned that in estimating a wiring system the voltage of the lamps to be used must be known.

But this is rather an unsatisfactory and rough method of arriving at the candle power and current. It will be seen from the table at p. 146, that the current and volts may vary considerably. But it is the custom to work the lamps at the highest practicable pressure, so that 100 volts is quite commonly put upon 16 c. p. lamps, and 120 volts upon 20 c. p. lamps; hence the "watts per candle" (p. 170) is as low as possible. The practice of the Edison-Swan Company is to indicate all lamps taking more than ·9 ampère at 4 watts per candle, and all lamps taking less than this amount at 3·5 watts per candle.

Roughly, an electrical engineer allows half an ampère per 100-volt lamp and one ampère per 50-volt lamp, in estimating his dynamo power.

According to this approximation the volts and ampères per 100 lamps of the 50-volt class will be, allowing for "fall," 55 volts and 100 ampères. For 100-volt lamps 105 volts and 50 ampères.

Methods of Jointing the Conductors.

Materials required.—A jointing-tool and material case, containing suitable receptacles for all the usual

tools and material; or a leather satchel, as used for linesmen's tools.

1 small bench vice, 1 hand vice.

1 insulation knife, 1 scissors.

1 flat file, medium cut.

1 pair flat-nose cutting pliers, 1 ditto plain, 1 ditto round nose.

1 lb. tinned wire, fine, for binding joints.

1 soldering iron.

1 portable soldering furnace, 1 appliance (Bunsen burner) for heating wire by gas, 1 spirit jointing-lamp.

½ lb. solder.

¼ lb. resin, in a box.

1 small bottle Baker's soldering fluid, or solution of zinc chloride.

3 sheets "F. F." emery cloth.

1 tin of india-rubber solution, 1 do. Chatterton's compound.

1 lb. each of ½-in. and 1-in. thin sheet wrapping india-rubber and india-rubber tissue.

1 lb. felt tape (compounded) for wrapping.

1 bottle strong, thick shellac varnish, 2 brushes.

1 ball spirit-lamp cotton, 1 tin best wood naphtha.

Instruments.—If the wiresman is also intrusted with the testing of his circuit (for continuity), he will require a linesman's galvanometer or detector, and a small dry battery of about six cells. Both the Leclanché and the chloride of silver cells are used for this purpose. These are usually combined in one case, with the necessary connecting wires.

Method of making a Common Joint in Gutta-percha-covered Wire.—Cut away the insulating material from both wires for about 2 inches. Do not notch the wire in doing this. Scrape the ends quite clean.

Place one conductor across the other near to the insulation, and grip fast with pliers or hand-vice according to size of wire. Twist the conductor ends over each other alternately until a neat, close spiral is obtained, at least $1\frac{1}{2}$ in. in length. Clip off the remaining copper ends, and trim smooth with the file. Again clean the joint by scraping. Apply a *very little* soldering fluid (or preferably, resin—see "Soldering"), and tin the joint with the iron. Wipe carefully, especially if fluid has been used, and it has not been all "burnt out" in the tinning. Proceed to stretch down the insulation from either side, over the joint. Keep the gutta-percha warm over the lamp while doing this. Tool the gutta-percha together with a warm iron where it meets, and allow it to set before finishing the joint. Put on a coat of Chatterton's compound in the middle of the joint, and allow to set. Take a strip of thin gutta-percha sheet several inches in length and an inch wide. Warm this up and attach one end to the joint. Keeping the rubber soft wrap it round the joint—it will form an enlargement. Before it cools work the wrapping in both directions with thumbs and fingers until it extends completely over the joint—it should be slightly thicker than the ordinary size of the insulated wire when done. Tool it smooth with a warm iron, leaving it smooth and compact. The joint should be capable of withstanding immersion in water even longer than the general insulation. It is essential that the hands and materials be clean.

Joint in an ordinary Taped Lead.—Unwind the insulation 4 inches from each end and strip off 2 inches of the interior gutta-percha. Scrape the metal clean. Splice or scarp the ends for $1\frac{1}{2}$ inches with

the file, so that when placed together they do not form a joint larger than the wire. Hold one end in the vice, place the other upon it. Touch with resin or soldering fluid and carefully solder together. File round, and bind upon the joint a close spiral of tinned wrapping wire. Solder all together. The covering will depend upon the insulation of the wire. Heat a long strip of gutta-percha and wrap it quickly around the warm joint. Work it lengthways until it combines with the insulation. Tool it down with a warm iron. Cover with a close winding of india-rubber coated tape, with coatings of india-rubber solution between. The exterior covering is generally compound-coated tape, carefully wound in several layers, combined with the tape unwound from the wire, with shellac varnish between each layer. Over all a coating of varnish. The joint must withstand continuous immersion in water.

A T*-joint or Branch from Main Lead.*—Strip, by unwinding, the insulation of the main lead for about 2 inches. Clean the copper. Strip the branch extremity for 4 inches, and clean it by scraping. Place the branch *across* the main at right angles. The branch should touch close up to its insulation, and it should cross the main to the extreme left of the bared portion. Hold in position with the pliers. Proceed to wind the branch around the main in a tight spiral. Apply resin or solution and solder together carefully. Wipe clean. Apply coating of shellac varnish. Wind cotton insulation from both conductors alternately around the main. Shellac and varnish over all. Wind on a strip of gutta-percha sheet while soft, and draw it well over the joint. Tool it down. Cover with several close windings of india-rubber-coated tape,

with coatings of solution between. Allow the solution to dry before proceeding. Over all wind two coverings of felt tape, with shellac varnish. The joint must be perfectly clean and smooth, and only slightly thicker than the main conductor. If the branch is liable to longitudinal strain, bring its end back and wind it several times around itself while winding bare upon the main. If the main is stranded, solder the strand together before winding in the branch.

Joint in a stranded Conductor.—Clear the insulation from either end for 3 inches. Separate the central strands and cut out both the central wires. Twist each pair of wires together separately. Twist all together and solder carefully. Make the insulation joint as before.

General Suggestions.—The operation of making a good joint calls for considerable practice. Carefully stripping the insulation, so that it may serve to lap the joint, is an important point. Cleaning and tinning must be thoroughly done. Connecting or splicing must be neat and strong. Wire wrapping must be close and neat. Tinning over all must be effective. The subsequent operation of insulating the joint is of the greatest importance in wiring. The wiresman must not forget that he is making *two* joints at one time—a metallic conducting joint and an *insulation joint.* The insulation joint must be quite as effective as the metallic joint. This is chiefly produced by the skilful use of soft gutta-percha, made to unite with the gutta-percha of the wire, or with tape and varnish, forming when dry a solid coating of insulation. Unless the joints in a lead be specially made to resist strain such a lead must never be subjected to tension

after being jointed. The main outlook in jointing is to produce continuity of conductor and continuity of insulation *at least* as good as that of the general run of the lead. Most skilful hands produce joints much more conductive and better insulated than the general run of the wire.

Soldering and Tinning.—A much-contested point amongst electrical engineers is whether resin or soldering fluid should be used as a flux. We think an answer may be readily found in the following :—If the workman is not thoroughly acquainted with the use of resin, in tinning copper, let him use fluid. A resin joint, unless very well made, is very deceptive, and may appear to be sound, when a coating of resin may exist between the ends to be united. If resin is properly and sparingly used, it no doubt makes the best joint for keeping, or permanency. The objection to chloride of zinc solution is that it is sometimes left upon the joints and may set up electrolytic action when current is on, speedily destroying the joint. If chloride of zinc be left on a joint that joint will never become dry. This salt is one of those that absorb moisture from the atmosphere. If left upon iron, or, indeed, almost any metal, it tends to set up oxidation—in the case of iron very rapid. *But there is no flux so certain in its action as soldering fluid.* There is a variety of it believed to be free from most of the objections to chlorine of zinc, known as Baker's tinning fluid. This kind is used exclusively by the Post Office electricians. If joints made with fluid can be washed and dried afterwards they will be quite safe; such a joint is never deceptive. The fluid "flux" will make a good joint on a surface so dirty that resin would never permit the iron to tin. The

main provision in soldering joints is cleanliness—pure, bright copper, untouched by hand.

All joints should be soldered.

Electric Lamps on Gas Fittings.—The failures that have resulted from making gas fittings act as a return wire, in some installations of the light, should be sufficient to dissuade any further experiments of the kind. *Gas fittings are not necessarily conductive* throughout—joints are generally faulty points.

But such a fitting as a chandelier may generally be made to serve as a "return," within itself only. That is, the two wires are brought to it, and one of them soldered to the ceiling fixture of the pendant, the other being taken downward to the lamps. Wire for this purpose must be very heavily insulated, and it must not be led or drawn over sharp angles of the metal, otherwise it may set up short-circuiting. When gas fixtures are to carry electric lamps only, the gas pipes should be disconnected from them, otherwise short circuits are apt to be got throughout the system.

If both gas and electricity are to be used, the fixtures should not, except within themselves, be used for return, and in any case it will be essential to observe that the *negative* wire (if that wire be regarded as the "return") is in every case soldered to the fixture, and not any wire at random, whether negative or positive. *Insulated joints* for insertion in gas systems are coming into use for cutting each fixture off electrically from the main system of pipes. The gas supply is kept up through a tube of insulating material.

All electric light wires must be kept a safe distance from gas or water pipes.

A fusible plug must be placed in the ceiling plate, above each pendant carrying more than one light.

It may be broadly stated that all electric light fixtures must be insulated from any metallic support they may have.

In the ordinary wiring of a chandelier the lead and branches are simply led along the course of the arms, concealed as much as possible. If the wires can be completely concealed, that is done by inserting them beneath the ornamental coverings or shells. One wire only is taken to each lamp. The other contact is got by soldering the negative terminal of the lamp, or its wire attachment, to the body of the chandelier. Thus, the pair of wires led to the ceiling opening over a chandelier will form a pair of "mains," and the branch wires the "branches."

In wiring gas fixtures in which there are joints the connection is kept up across the joints by short spirals of insulated wire, flexible enough to move with the joints without danger of breakage.

Electric light fixtures, intended for that purpose alone, are generally already wired by the makers, and are specially adapted, so that their fitting is a comparatively simple matter. There is usually provision left in the ceiling rosette, or wall-plate, to allow of the insertion of a fusible plug there—a precaution which is generally observed in the case of electroliers with several lamps attached.

The fitting of the incandescence bulbs themselves to the gas fixtures is greatly facilitated by the use of "*adapters*," consisting of screwed nozzles fitted to the lamp, and with gas thread to take the place of the ordinary burners, usually $\frac{3}{8}$ in. gas thread. But it is rather unusual and unnecessary to attach the glow lamps so that they take a vertical position, as in the case of gas burners. It is generally more effective to

arrange them pendant from the chandelier. This is easily effected by the use of "*pendant arms*" with screwed nipples, to be fixed in the place of the gas burners. The lamps can, by these means, be arranged either pendant or at an angle of 45° with the vertical —a favourite and effective position for an incandescent lamp.

CHAPTER VI.

INCANDESCENT LIGHTING OF SHIPS.

THE rapid adoption of electric light aboard steamships has caused a considerable demand for information on the subject. We propose therefore to offer a few hints and suggestions bearing upon the condition of things suitable for use at sea. But the subject is so wide that ship lighting might well require a treatise of considerable size to fully do it justice. Premising, however, that the reader seeking this special information is already acquainted with what we have written on house lighting, it may be practicable to embrace the chief points of interest within even the restricted space at our disposal.

Dynamos.—For use aboard ship there can be no doubt that slow speed dynamos give the least trouble. The importance of providing a ship with electric machinery that calls for little attention can only be appreciated by those who have been at sea, where the electric lighting has usually to be looked after by the engineers in turn as they come on watch. The mechanical engineers, although perfectly competent in their profession, are not to be expected to pose as experts in the handling of dynamos or faulty circuits. Hence, apart from mere mechanical attention, the ship dynamo should not need any kind of supervision. This condition is perhaps better filled by a compound-

(series and shunt) wound dynamo, running at a slow speed, than by any other kind of machine. It must give a self-regulating current and pressure suited to the lamps. The compound-wound dynamo, if well designed, can be made to regulate so closely that if half the lamps be suddenly turned off or on scarcely a flicker will be observed in the remaining lamps. A ship dynamo should be self-regulating down to at most 10 per cent. of the lamps.

If 100-volt lamps be used, the dynamo is generally selected to give a pressure of 110 volts at least, with a minimum of half an ampère of current for each lamp. Thus, if 1000 hundred-volt lamps are to be run, the dynamo must give at normal speed 500 ampères at 110 volts.

If 50-volt lamps be used, as is generally the case aboard ship, the dynamo must give a current of 1000 ampères at 55 to 60 volts. These figures are approximate only, depending upon the "watts per candle" of the lamps to be used; upon the size of the leading wires and the insulation employed. The lower pressure and larger leading wires are doubtless most suitable for ships; but the expense of running the light is somewhat greater than when high voltage lamps are used. The volts of the dynamo should in no case be less than 50, on account of the necessity for the use of arc lamps aboard ship, for canal navigation and unloading or loading at night.

Driving.—A good deal of controversy has taken place as to the comparative advantages of belt and direct driving. There can, we think, be little doubt that direct driving—attaching the dynamo direct to the engine shaft—is the most generally applicable plan. Several special engines have been designed

for this purpose. A special separate engine, nicely self-regulating, is an absolute necessity. The main engines of a steamship in rough weather run at all speeds, and cannot be utilised for driving a dynamo if the machine is used for lighting lamps direct. Main-engine driving has, however, been tried where the lamps have been run off an accumulator. But if it comes to a question of special engine *versus* accumulator, the engine has decidedly the best of the case. A large battery of accumulators is scarcely suitable aboard a ship, unless the vessel carry a qualified electrician to run the plant.

While speaking of accumulators it may be mentioned that a small battery of them is extremely useful for keeping the "all night" lights going, after the dynamo has been stopped. Such a battery is usually charged by running the dynamo upon it during the day. But for ship work a battery of 26 cells appears quite sufficient. Such an installation can only be run satisfactorily when tended by a man acquainted with both dynamos and accumulators. For further information as to the running of accumulators the reader is referred to Chapter II., p. 42.

Disturbance of the Compasses in Ship Lighting.

The "Nautical Magazine" for December, 1885, contains a contribution from Mr. William Bottomley on the subject of the probable interference with the compasses by the currents used for the electric light. The following example of a supposed case showing the amount of error which may be produced on the compass unless precautions are taken to guard against it is there given :—

Suppose a main lead from the engine room to the fore part of the ship to light up 100 lamps is brought along the centre of the ship. It may be at a distance of 10 metres or 33 feet from the standard compass, and will run almost underneath it. If we suppose that each lamp takes one ampère of current, there will be a current of 100 ampères altogether in this lead.* Now the effect on the compass at a distance D in centimetres is given by the formula

$$F = \frac{2 \times \frac{1}{10} C}{H D},$$

where C is the current in ampères and H is the horizontal magnetic force. In this case we have C = 100 ampères and D = 1000 centimetres. Therefore

$$F = \frac{20}{1000\ H} = \frac{0{\cdot}02}{H}.$$

At Glasgow the horizontal force may be taken as 0·15 in C.G.S. units. Therefore the effect upon the compass will be $\frac{\cdot 02}{\cdot 15} = \frac{1}{7{\cdot}5}$. This will be expressed in degrees by multiplying by 57·3 the number of degrees in the radian, or angle subtended at the centre of a circle, by an arc equal in length to the radius. Therefore the amount of error produced by such a current on the compas will be

$$\frac{57{\cdot}3}{7{\cdot}5} = 7{\cdot}6 \text{ degrees.}$$

The foregoing refers to a single wire and a continuous current machine, but if an alternate current machine is employed no effect will be produced on the compass, even when the ship's side is used for the

* It is unusual, however, to put more than 50 lamps upon a single lead.

return. When a continuous current machine is used the danger of producing an error on the compass can be avoided by using two wires close to one another, but these wires should be well insulated from the ship's side. If in any way one of the wires is brought in contact with the iron of the ship, there may be no change observable in the lighting, but the current may produce as much error on the compass as it would if there was only a single wire.

The following points should therefore be attended to in cases of lighting ships by electricity :—

When a continuous current machine is used the circuit should consist of leading and return wires, as in house lighting, with this difference, that the wires should be kept close together wherever practicable.

Insulation resistance should be tested periodically to ascertain if there be any leakage to the ironwork of the ship.

These precautions are recommended because in ship lighting, as commonly carried out, only a leading wire is used, the "return" being effected through the shell of the ship itself, *e.g.*, no negative wire is used.

In the case of an alternate current machine a single wire may be employed, and the iron of the ship used to complete the circuit without producing any effect upon the compass.

Error not readily Detected.—The question assumes greater importance when we consider that the error of the compass due to the electric lighting is not liable to come under the notice of the officers of the vessel. The routine is to determine the error (the usual working error) of the compass during the day, while the electric light is not employed. The error may thus be determined as usual every day, and the course of

the ship set by these determinations; but when the electric light is turned on, the course of the vessel may be changed, and before the light is turned off she may be several degrees out of her path.

Mr. Bottomley refers to the case of a dynamo being placed near to an iron bulkhead, the upper end of which happens to be near to the compass. It is assumed that the bulkhead may become so strongly magnetised by the field magnet of the dynamo that a considerable error may be produced on the compass.

In the discussion that followed a paper read by Mr. Bottomley at the Society of Arts,* in which several authorities on the subject took part, including Captain Creak, of the Admiralty Compass Department, the case of three ships lighted on the single-wire system with continuous currents was cited, in which distinct error had been observed upon the compasses when the lights were turned on.

Sir William Thomson † mentions cases of large passenger ships lighted by continuous current on the single-wire system, in which as much as 4° and 5° of error on the compasses had been produced by the electric lighting. In the latest of these cases an error of 4° on the north course was found when the light was turned on. The light was put on and off several times with the ship's head north, and every time the same error was produced.

Mr. Alexander Siemens, another well-known authority on this subject, points out that in calculations that have been made to show the effect upon the compass of the electric-lighting current, the screening effect of the iron decks had been neglected. He is

* "Journal of the Society of Arts," Feb. 5, 1886.

† See paper on the subject read before the Institute of Electrical Engineers, May, 1889.

of opinion, judging from practical experience, that two wires are unnecessary, and that the disturbance of compasses is only brought about by running single leads close to them, or situating the dynamo in immediate proximity.

Captain Creak instanced the case of a war ship, in which the direct compass disturbance due to the generating machine was appreciable at a distance of 55 ft., and across iron bulkheads, and that it was perceptible also in ships of the Royal Navy lighted on the two-wire system. In the case of H.M.S. *Northampton* there was considerable trouble due to "magnetic leakage" from three dynamos placed in such a position that the external field produced was directed towards the compass. The error on the compass was 11° when all the machines were running, and three correction tables were necessary.

Test for Compass Disturbance due to the Currents.—It is now usual, since attention has been called to the subject, to apply a test before the ship leaves dock to have her compasses adjusted. This is simply effected by putting on and off the lights, and observing the compass. This is done as the needle stands, and also after it has been artificially deflected from its position to the extent of 45° on either side of zero by means of a small permanent magnet suspended above the glass case.

It is clear, from the extensive experience that has been gained on the subject, that by the use of dynamos diffusing little magnetic leakage—possessing a compact magnetic field directed only upon the armature—as now constructed the faults due to this factor can be overcome. The dynamo must of course be kept as far as practicable from the compass.

There can be no doubt also that hundreds of ships have been supplied with electric light on the single-wire system, in which the error on the compasses is very slight, if at all appreciable.

This is usually effected by keeping the leading wire as near to the ship's side as possible, and by observing that some iron screen, as the upper deck, interposes itself between current and compass.

Ship Wiring.

So much has already been said with regard to house wiring that only the main peculiarities of the methods observed in ships need be noticed.

Single-wire Work.—Since there is no return wire, and since, by connecting the negative poles of the lamps to the iron work of the ship, the negative is practically earthed, *very good insulation* must be used. The wire employed must first have a conductivity at least as high as 95 per cent. It must be insulated in a very thorough manner with pure india-rubber, combined with cotton insulation or other substance, and completely vulcanised, as spoken of at p. 150. The exterior protection must be strong, and adapted to withstand the roughest handling. The rules given at p. 86 will apply to the covering of the cable, and at p. 146 to the selection of a conductor of sufficient carrying capacity. In ship wiring, when the wires can scarcely be kept free from damp, the insulation must be especially effective.

The general opinion is in favour of simple cleat wiring, without casings, when it can be employed, below decks. The cleats used are single-groove cleats.

Connection with the dynamo is got by bringing a thick piece of cable from its negative terminal and making a good connection to a large copper or gun-metal stud screwed into the iron work of a bulkhead, or any main piece of the ship's shell. The leading cable's insulation covering is kept away from actual contact with the iron work. When it is run along the ship's side or under an iron deck "runners" of wood are interposed. These runners should be varnished or soaked in melted paraffin wax, to prevent the absorption of moisture. It is usual to run the lead under the main deck, and to take from it branch wires to the lamps to be fed. In the case of a single lamp, situated away from other lamps, its negative or *return* would be made by attaching the terminal by means of a short piece of copper wire to a brass stud screwed into the nearest iron work. In the case of groups of lamps one such stud is made to answer for several lights. These are known as "return studs."

Joints in the leading cable are usually not only made with extra care, but are afterwards protected by cast-iron joint boxes, and the same boxes are generally fixed over connections to branches, at which point also a fuse is of course inserted.

Precautions against fire are taken by the use of double-pole fuses at the dynamo, and the insertion of one at every branch root, and frequently a fuse is inserted for single lamps. A fuse is of course put to every cluster of lamps, as in house wiring.

The wiring of ships is generally carried out on the parallel system (p. 125), with only one lamp between lead and ship. The tension employed, as already stated, is not often over 50 or 60 volts.

The two-wire system is not so extensively used as

it should be. When it is installed the insulation of the wire need not be so heavy as is required in the single-wire system, and with a view to the protection of the compasses the lead and return should, when practicable, be run within a few inches of each other.

Saloon and cabin wiring must be done under casings or mouldings, as explained at p. 177. There is one point in wiring a ship that should receive attention. Insulated wire does not last in use indefinitely. It may have to be renewed every few years. For this and other reasons the position of the wires should be such that they may be accessible for purposes of repair or renewal.

Ship fittings are a class of themselves. They are usually of a very solid make. The bulkhead and engine-room and passage-way lamps are placed behind glass screens, and protected by iron gratings. Side lights are also coming into use, fed from a branch taken from the nearest main. Each cabin lamp has its own switch. The saloon lights are controlled by the attendants by means of a main switch.

The main switch-board is generally placed in the dynamo room, which is usually the engine room, and is fitted to control (1) the "cabin's circuit," (2) the "saloon's circuit," (3) the "officers and men's circuit," separately, as may be convenient. Thus there are frequently a number of separate circuits run, so that any one section of lamps may be controlled separately. It is rarely that more than 50 lamps are placed in a single circuit.

Compass Electric Lamps.—These have been tried, but not with much success. Major Cardew stated * that he had carefully twisted the two leading wires to-

* Meeting of the Institute of Electrical Engineers, May 23, 1889.

gether to eliminate the effect of their induction upon the compass, but that the current in the filament of the lamp itself affected the compass, and introduced an error. Better results have followed the use of metallic induction screens for obviating this inductive effect, and there can be no doubt that binnacle lamps lighted by the current will soon become the best possible source of light for a compass in rough weather.

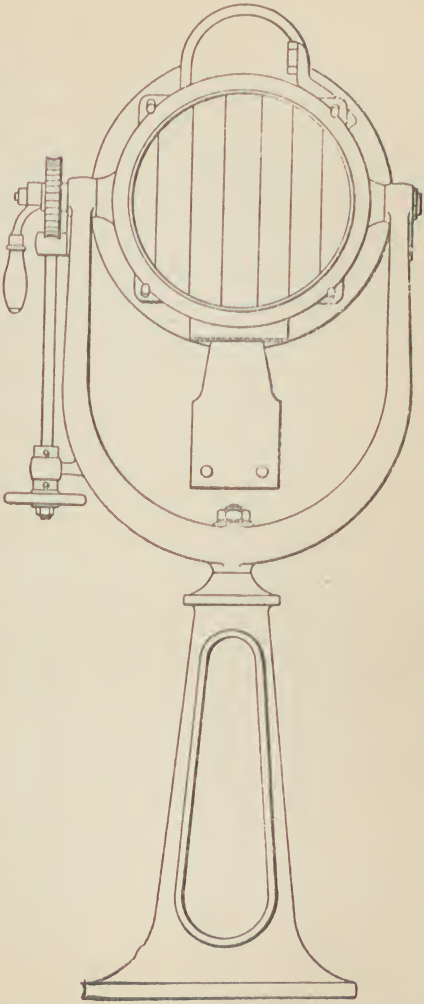

Fig. 88.—Suez Canal Projector—Front Elevation.

Suez Canal Projector.—Owing to the successful use of the electric arc light the traffic has been carried on through the Suez Canal by night for some years past.

The arc lamp is placed within a projector usually

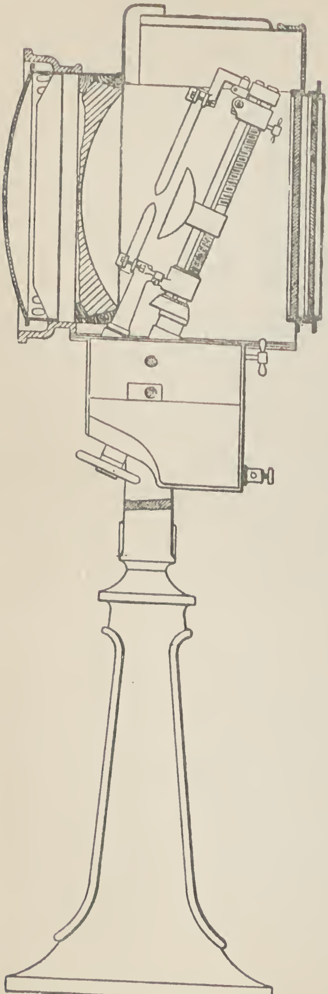

Fig. 89.—Suez Canal Projector—Section.

arranged as in Figs. 88 and 89, which represents the form fitted to ships by Messrs. Paterson & Cooper. The projecting portion, shown in front elevation in Fig. 88, and in section in Fig. 89, is controlled by the hand wheel and worm-gearing shown. The front of the projector is fitted with the usual optical appliance for concentrating the beam in a given path. These projectors are generally slung over the bow of the ship, at such a height above the water as will give the best effect. The projector is generally placed in a cage, and is kept in adjustment by an attendant who occupies the back of the cage. The maximum current put upon the projector is 60 ampères at a pressure of 50 volts, and it is now common to run it off the dynamo employed for the general lighting of the ship. A "choking coil" is usually

placed in series with the arc lamp, absorbing about 15 volts.

Electric projectors and apparatus are frequently hired by vessels passing through the Canal, when they do not carry a dynamo, or when the lighting plant aboard is working up to its full power on the general lighting of the ship. The night navigation of the Canal is very greatly facilitated by the free use of arc lamps placed along its sides for considerable distances. If this system were extended it is probable that the use of projectors aboard the vessels would be unnecessary.

CHAPTER VII.

MISCELLANEOUS INFORMATION.

Abstract from the "Rules" recommended by the Institute of Electrical Engineers.—The committee appointed by the Institute, consisting of gentlemen well known in electrical circles, make, amongst others, the following suggestions, chiefly bearing upon the fire risks of electric lighting:—

Conductors.

Carrying Capacity.—Conductors must have a sectional area and conductivity so proportioned to the work they have to do that if double the current proposed is sent through them the temperature of such conductors shall not exceed 150° Fahr.

Accessibility.—The conductors or their casings should be placed in sight if possible, and they should always be as accessible as circumstances will permit.

Insulation.—Within buildings they should always be insulated, and this rule applies equally to all conductors and parts of fittings which may have to be handled.

Highest Permissible Temperature.—Whatever insulating material is employed it should not soften until

a temperature of 170° Fahr. has been reached, and in all cases the material must be damp proof.*

Casings.—When conductors pass through roofs, floors, walls, or partitions, and when they cross, or are liable to touch metallic substances, such as bell wires, iron girders, or pipes, they should be thoroughly protected by suitable additional covering; and when they are liable to abrasion from any cause, or to the depredations of rats or mice, they should be encased in some suitable hard material.

Portable Lamps.—In the case of portable lamps and fittings with which flexible leads are used special precautions must be taken.

Distance Apart.—Conductors should be kept as far apart as circumstances will permit, the spacing between them being governed by their potential differences.

Inflammable Structures.—When conductors in very inflammable structures precautions should be taken to isolate them therefrom.

Metallic Protection.—Conductors which are protected on the outside by lead or metallic armour of any kind require the greatest care in fixing, on account of the large conducting surface, which would become connected to the core in the event of metallic contact between them.

Dangers from Operations through Walls.—In cases where conductors pass into a building—from one building to another, or from one room to another—precautions should be taken to prevent the possibility

* It may be noted, in reference to this rule, that, as gutta-percha softens at 115° F., becomes plastic at 120° F. and melts at 212 F., it is practically excluded as an insulator of wires when unsupported by other, and infusible, insulating coatings around the conductor. Vulcanised india-rubber withstands much higher temperatures.

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of fire or water passing along the course of the conductors.

Joints.—All joints must be mechanically and electrically perfect, to prevent heat being generated at these points. When soldering fluids are used in making joints the latter should be carefully washed and dried before insulation is applied.

Gas and Water Pipes.—Under all circumstances complete metallic circuits must be employed. Gas and water pipes must never form part of the circuit, as their joints are rarely electrically good, and therefore become a source of danger.

Overhead Conductors.—Overhead conductors, whether passing over or attached to buildings, must be insulated at their points of support. Precautions must be taken to obviate all risk of short-circuiting when they are likely to touch a building or other overhead conductors and wires, either by their own fall or by being fallen upon by other conductors.

Lightning Protectors.—In the case of overhead wires every main should have a lightning protector at each point when it enters or branches into a building.

Metal Fastenings.—Metallic fastenings for fixing conductors should be avoided; but, when unavoidable, some additional covering should protect the conductor from mechanical injury at such fixing points.

Insulation Resistance.—The insulation of a system of distribution should be such that the greatest leakage from any conductor to earth (and, in case of parallel working from one conductor to the other, when all branches are switched on, but the lamps, motors, etc., removed) does not exceed *one five* thou-

sandth part ($\frac{1}{5000}$) *of the total current* intended for the supply of the said lamps, motors, etc.; the test being made at the usual working electromotive force.

Switches.

The main switches of a building should be placed as near as possible to the point of entrance of the conductors, or to the generators of the current. Switches should be provided in both leads.

Bases.—Switches, commutators, resistances, bare connections, lamps, &c., must be mounted on incombustible bases. Cut-outs mounted on bases of wood rendered uninflammable are admissible. Vulcanite bases are undesirable in damp situations.

Cut-outs.

All circuits should be protected with cut-outs; and all leads from the mains, or small conductors from larger ones, must be fitted with cut-outs at their branching points.

When fusible cut-outs are used the section should be so situated within its frame that the fused metal cannot fall where it may cause a short circuit or an ignition.

For all main conductors a cut-out should be provided for both the "flow" and the return (+ and — leading wires); and the two fusible sections must not be in the same compartment.

Arc Lamps.

These must be guarded by lanterns or netted globes, so as to prevent danger from ascending sparks, and from falling glass and incandescent pieces of carbon.

Transformers.

When these are used to transform either direct or alternating currents of high electromotive force—that is, from or to an electromotive force of, say, 2000 volts—they, together with their switches and cut-outs, must be placed in a fire and moisture proof structure, preferably outside the building for which they are required. No part of such apparatus should be accessible except to the person in charge of their maintenance.

Distance between + and − Terminals.—The positive and negative terminals connected to such conductors should not be permitted to be nearer each other than 12 inches.

Heating.—Transformers which, under normal conditions of lead, heat above 150° Fahr., should not be permitted to remain in use.

Danger from Internal Contact.—Transformers should be so constructed that under no circumstances whatever should a contact between the primary and secondary coils lead a high E.M.F. into the building.

These amended rules (certain paragraphs not pertinent to our subject, or already abundantly treated, have been left out) were issued by the Institute of Electrical Engineers, April, 1888.

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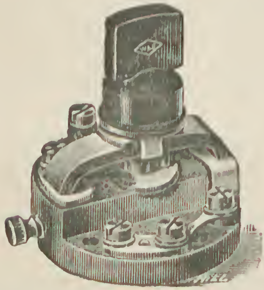

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